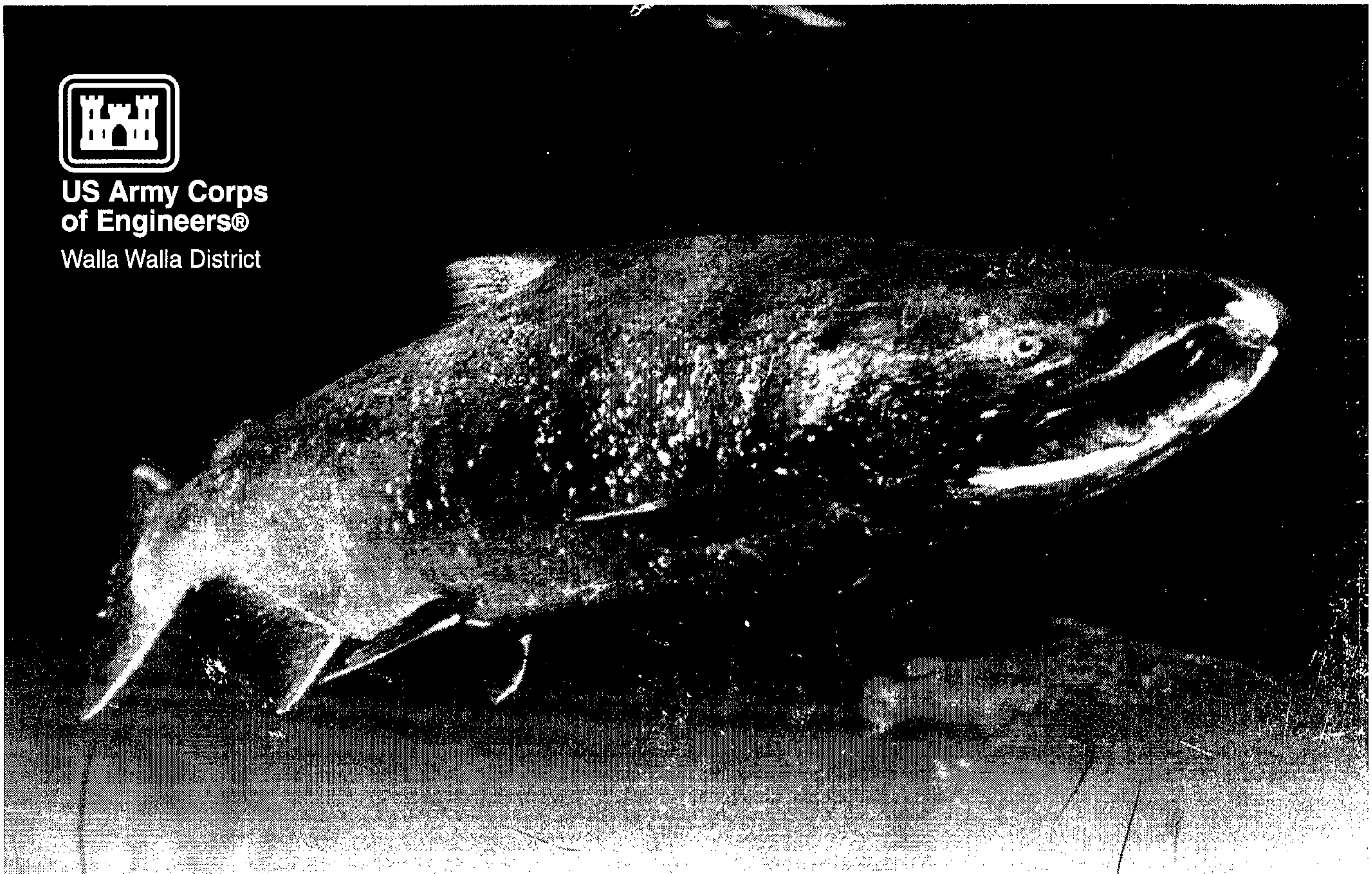


# DRAFT

# Lower Snake River Juvenile Salmon Migration Feasibility Report/ Environmental Impact Statement

## APPENDIX G
## Hydroregulations



December 1999

| REPORT DOCUMENTATION PAGE | Form Approved OMB No. 0704-0188 |
|---|---|



| 1. AGENCY USE ONLY *(Leave blank)* | 2. REPORT DATE | 3. REPORT TYPE AND DATES COVERED |
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| | December 17, 1999 | Draft 17 Dec 99 - 31 Apr 00 |

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13. ABSTRACT *(Maximum 200 words)*

The Corps of Engineers along with the Bonneville Power Administration, US Environmental Protection Agency, and US Bureau of Reclamation as cooperating agencies, analyzed four general alternatives intended to provide information on the technical, environmental, and economic effects of actions related to improving juvenile salmon passage. The four alternatives include Alternative 1 - Existing Conditions (the no-action alternative) and three different ways to further improve juvenile salmon passage. The action alternatives are: Alternative 2 - Maximum Transport of Juvenile Salmon, Alternative 3 - Major System Improvements, and Alternative 4 - Dam Breaching. Comparison of the alternatives by all of the factors assessed in the study has not offered a clear-cut recommendation at this time. It is the Corps of Engineer's intent to recommend a preferred plan of action in the Final FR/EIS.

| 14. SUBJECT TERMS | 15. NUMBER OF PAGES |
|---|---|
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| 17. SECURITY CLASSIFICATION OF REPORT | 18. SECURITY CLASSIFICATION OF THIS PAGE | 19. SECURITY CLASSIFICATION OF ABSTRACT | 20. LIMITATION OF ABSTRACT |
|---|---|---|---|
| UNCLASSIFIED | UNCLASSIFIED | UNCLASSIFIED | UL |

# FEASIBILITY STUDY DOCUMENTATION

| Document Title | |
|---|---|
| Summary to the Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental Impact Statement | |
| Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental Impact Statement | |
| Appendix A | Anadromous Fish |
| Appendix B | Resident Fish |
| Appendix C | Water Quality |
| Appendix D | Natural River Drawdown Engineering |
| Appendix E | Existing Systems and Major System Improvements Engineering |
| Appendix F | Hydrology/Hydraulics and Sedimentation |
| Appendix G | Hydroregulations |
| Appendix H | Fluvial Geomorphology |
| Appendix I | Economics |
| Appendix J | Plan Formulation |
| Appendix K | Real Estate |
| Appendix L | Lower Snake River Mitigation History and Status |
| Appendix M | Fish and Wildlife Coordination Act Report |
| Appendix N | Cultural Resources |
| Appendix O | Public Outreach Program |
| Appendix P | Air Quality |
| Appendix Q | Tribal Consultation/Coordination |
| Appendix R | Historical Perspectives |
| Appendix S | Snake River Maps |
| Appendix T | Biological Assessment |
| Appendix U | Clean Water Act, Section 404(b)(1) Evaluation |

The documents listed above, as well as supporting technical reports and other study information, are available on our website at www.nww.usace.army.mil. Copies of these documents are also available for public review at various city, county, and regional libraries.

# FOREWORD

This appendix is one part of the overall effort of the U.S. Army Corps of Engineers (Corps) to prepare the Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental Impact Statement (FR/EIS).

Please note that this document is a DRAFT appendix and is subject to change and/or revision based on information received through comments, hearings, workshops, etc. After the comment period ends and hearings conclude a Final FR/EIS with Appendices is planned.

The Corps has reached out to regional stakeholders (Federal agencies, tribes, states, local governmental entities, organizations, and individuals) during the development of the FR/EIS and appendices. This effort resulted in many of these regional stakeholders providing input, comments, and even drafting work products or portions of these documents. This regional input provided the Corps with an insight and perspective not found in previous processes. A great deal of this information was subsequently included in the Draft FR/EIS and Appendices, therefore, not all the opinions and/or findings herein may reflect the official policy or position of the Corps.

# STUDY OVERVIEW

## Purpose and Need

Between 1991 and 1997, due to declines in abundance, the National Marine Fisheries Service (NMFS) made the following listings of Snake River salmon or steelhead under the Endangered Species Act (ESA) as amended:

- sockeye salmon (listed as endangered in 1991)
- spring/summer chinook salmon (listed as threatened in 1992)
- fall chinook salmon (listed as threatened in 1992)
- steelhead (listed as threatened in 1997)

In 1995, NMFS issued a Biological Opinion on operations of the Federal Columbia River Power System. The Biological Opinion established measures to halt and reverse the declines of these listed species. This created the need to evaluate the feasibility, design, and engineering work for these measures.

The U.S. Army Corps of Engineers (Corps) implemented a study after NMFS's Biological Opinion in 1995 of alternatives associated with lower Snake River dams and reservoirs. This study was named the Lower Snake River Juvenile Salmon Migration Feasibility Study (Feasibility Study). The specific purpose and need of the Feasibility Study is to evaluate and screen structural alternatives that may increase survival of juvenile anadromous fish through the Lower Snake River Project (which includes the four lowermost dams operated by the Corps on the Snake River—Ice Harbor, Lower Monumental, Little Goose, and Lower Granite dams) and assist in their recovery.

## Development of Alternatives

The Corps completed an interim report on the Feasibility Study in December 1996. The report evaluated the feasibility of drawdown to natural river levels, spillway crest, and other improvements to existing fish passage facilities. Based in part on a screening of actions conducted in the interim report, the study now focuses on four courses of action:

- Existing conditions (currently planned fish programs)
- System improvements with maximum collection and transport of juveniles (without major system improvements such as surface bypass collectors)
- System improvements with maximum collection and transport of juveniles (with major system improvements such as surface bypass collectors)
- Dam breaching or permanent drawdown to natural river levels for all reservoirs

The results of these evaluations are presented in the combined Feasibility Report (FR) and Environmental Impact Statement (EIS). The FR/EIS provides the support for recommendations that will be made regarding decisions on future actions on the Lower Snake River Project for passage of juvenile salmonids. This appendix is a part of the FR/EIS.

## Geographic Scope

The geographic area covered by the FR/EIS generally encompasses the 140-mile long lower Snake River reach between Lewiston, Idaho and the Tri-Cities in Washington. The study area does slightly vary by resource area in the FR/EIS because the affected resources have widely varying spatial characteristics throughout the lower Snake River system. For example, socioeconomic effects of a permanent drawdown could be felt throughout the whole Columbia River Basin region with the most effects taking place in the counties of southwest Washington. In contrast, effects on vegetation along the reservoirs would be confined to much smaller areas.

## Identification of Alternatives

Since 1995, numerous alternatives have been identified and evaluated. Over time, the alternatives have been assigned numbers and letters that serve as unique identifiers. However, different study groups have sometimes used slightly different numbering or lettering schemes and this has lead to some confusion when viewing all the work products prepared during this long period. The primary alternatives that are carried forward in the FR/EIS currently involve four major alternatives that were derived out of three major pathways. The four alternatives are:

| Alternative Name | PATH[1/] Number | Corps Number | FR/EIS Number |
|---|---|---|---|
| Existing Conditions | A-1 | A-1 | 1 |
| Maximum Transport of Juvenile Salmon | A-2 | A-2a | 2 |
| Major System Improvements | A-2' | A-2c | 3 |
| Dam Breaching | A-3 | A-3a | 4 |

[1/] Plan for Analyzing and Testing Hypotheses

## Summary of Alternatives

The **Existing Conditions Alternative** consists of continuing the fish passage facilities and project operations that were in place or under development at the time this Feasibility Study was initiated. The existing programs and plans underway would continue. Project operations, including all ancillary facilities such as fish hatcheries and Habitat Management Units (HMUs) under the Lower Snake River Fish and Wildlife Compensation Plan (Comp Plan), recreation facilities, power generation, navigation, and irrigation would remain the same unless modified through future actions. Adult and juvenile fish passage facilities would continue to operate.

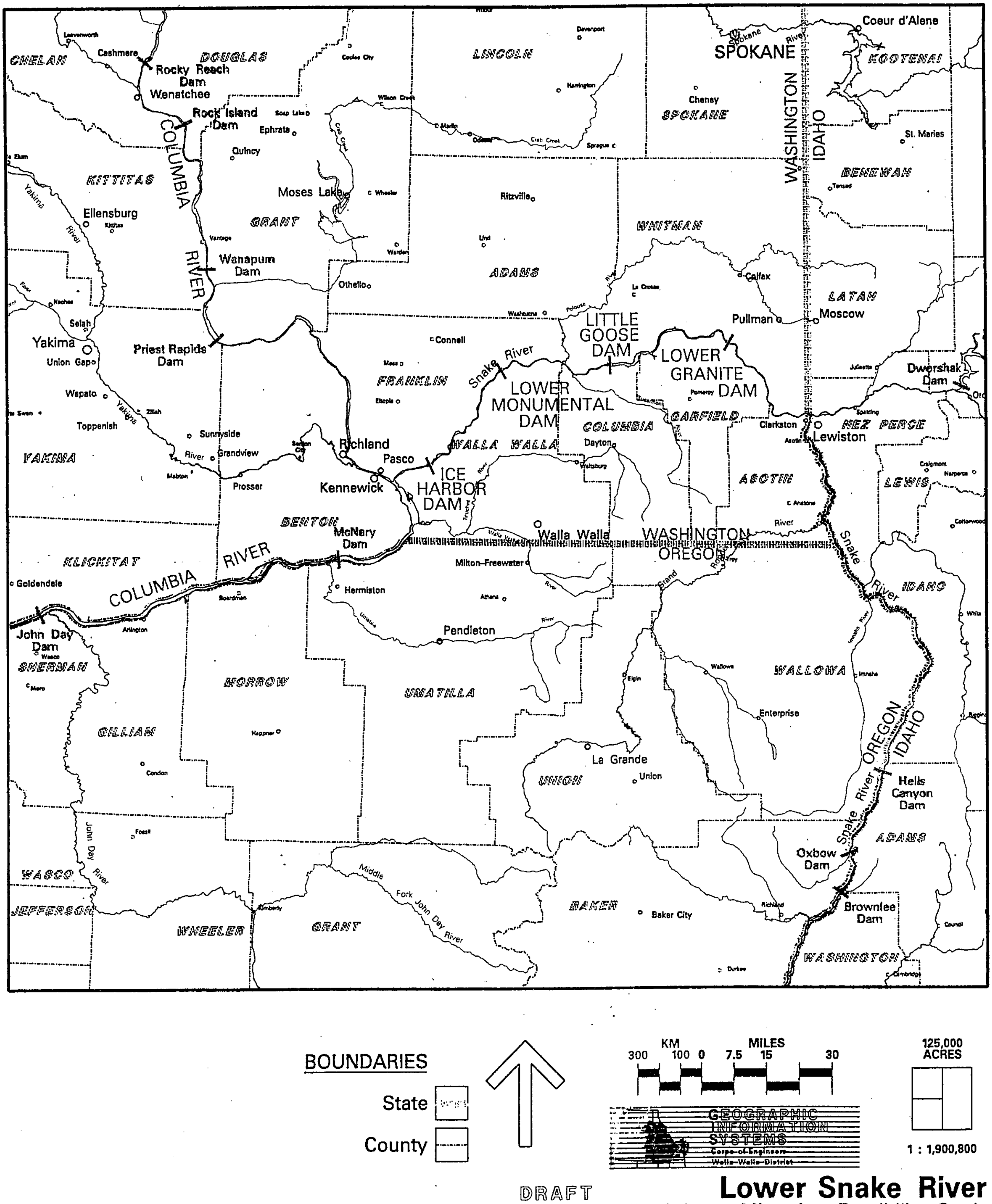
The **Maximum Transport of Juvenile Salmon Alternative** would include all of the existing or planned structural and operational configurations from the Existing Conditions Alternative. However, this alternative assumes that the juvenile fishway systems would be operated to maximize fish transport from Lower Granite, Little Goose, and Lower Monumental and that voluntary spill would not be used to bypass fish through the spillways (except at Ice Harbor). To accommodate this maximization of transport some measures would be taken to upgrade and improve fish handling facilities.

The **Major System Improvements Alternative** would provide additional improvements to what is considered under the Existing Conditions Alternative. These improvements would be focused on using surface bypass collection (SBC) facilities in conjunction with extended submersible bar screens (ESBS) and a behavioral guidance system (BGS). The intent of these facilities is to provide more effective diversion of juvenile fish away from the turbines. Under this alternative the number of fish collected and delivered to upgraded transportation facilities would be maximized at Lower Granite, the most upstream dam, where up to 90 percent of the fish would be collected and transported.

The **Dam Breaching Alternative** has been referred to as the "Drawdown Alternative" in many of the study groups since late 1996 and the resulting FR/EIS reports. These two terms essentially refer to the same set of actions. Because the term drawdown can refer to many types of drawdown, the term dam breaching was created to describe the action behind the alternative. The Dam Breaching Alternative would involve significant structural modifications at the four lower Snake River dams allowing the reservoirs to be drained and resulting in a free-flowing river that would remain unimpounded. Dam breaching would involve removing the earthen embankment sections of the four dams and then developing a channel around the powerhouses, spillways, and navigation locks. With dam breaching, the navigation locks would no longer be operational, and navigation for large commercial vessels would be eliminated. Some recreation facilities would close while others would be modified and new facilities could be built in the future. The operation and maintenance of fish hatcheries and Habitat Management Units (HMUs) would also change although the extent of change would probably be small and is not known at this time. Project development, design, and construction span a period of nine years. The first three to four years concentrate on the engineering and design processes. The embankments of the four dams are breached during two construction seasons at year 4-5 in the process. Construction work dealing with mitigation and restoration of various facilities adjacent to the reservoirs follows dam breaching for three to four years.

**Authority**

The four Corps dams of the lower Snake River were constructed and are operated and maintained under laws that may be grouped into three categories: 1) laws initially authorizing construction of the project, 2) laws specific to the project passed subsequent to construction, and 3) laws that generally apply to all Corps reservoirs.




DRAFT

# Lower Snake River
Juvenile Salmon Migration Feasibility Study

# REGIONAL BASE MAP
1999

GIS Analysts & Graphic Assembly: Applied Technology Team (CENWW-PM-PD-E)
g:\regional\reg\plates\lsr\jsmeis\lsrg\lsrgbmgm.dgn:GISFILE PLOTTED: 25 OCT 1999

# ABSTRACT

This is the Hydroregulation Technical Appendix to the Lower Snake River Juvenile Salmon Migration Feasibility Study. It was prepared by the U.S. Army Corps of Engineers (Corps), Northwestern Division, North Pacific Region, Water Management Division together with a hydroregulation work group comprised of the Corps, the Bonneville Power Administration, the Bureau of Reclamation, the National Marine Fisheries Service, the U.S. Fish and Wildlife Service, the Northwest Power Planning Council, the Columbia River Inter Tribal Fish Commission, and Washington, Oregon, and Idaho. This appendix describes the assumptions and results of computer modeling used to define the impacts and accomplishments alternatives investigated in this study. Results were then used by other workgroups to understand the effects of the formulated alternatives on other project purposes. The appendix illustrates changes to the Columbia River Basin, excluding the Upper Snake River above Brownlee Reservoir, in river flows, reservoir elevations, energy production, and spill for each alternative investigated.

US Army Corps
of Engineers®
Walla Walla District

# Draft

# Lower Snake River Juvenile Salmon Migration Feasibility Report/ Environmental Impact Statement

## Appendix G
## Hydroregulations


Produced by
U.S. Army Corps of Engineers
Walla Walla District



Completed December 1999
Revised and released for review
with Draft FR/EIS
December 1999

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# TABLES

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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ΔS | change in reservoir storage |
| AER | Actual Energy Regulation |
| aMW | average megawatts |
| AOP | Assured Operating Plan |
| ARC | Assured Refill Curve |
| AVE | Average |
| BoR | Bureau of Reclamation |
| BPA | Bonneville Power Administration |
| cfs | cubic feet per second |
| CMS | cubic meters per second |
| Corps | U.S. Army Corps of Engineers |
| CRC | Critical Rule Curve |
| DOP | Detailed Operating Plan |
| DWR | Dworshak Project |
| E | Efficiency |
| ESA | Endangered Species Act |
| Feasibility Study | Lower Snake River Juvenile Salmon Migration Feasibility Study |
| FELCC | Firm Energy Load Carrying Capability |
| fmsl | feet above mean sea level |
| ft | feet |
| GCL | Grand Coulee Project |
| H | Head |
| HGH | Hungry Horse Project |
| HYDREG | Hydro Regulator Model |
| HYDROSIM | Hydro Simulator Model |
| HYSSR | Hydro System Seasonal Regulation Program |
| I | reservoir inflow |
| IHB | Ice Harbor Project |
| IJC | International Joint Commission |
| KAF | thousand-acre-feet |
| khm | kilo-hectare-meter |
| ksfd | thousand-second-feet-days |
| KW | kilowatts |
| L | losses |
| LGS | Little Goose Project |
| LIB | Libby Project |
| LMN | Lower Monumental Project |
| LWG | Lower Granite Project |
| m | meters |
| MAF | million-acre-feet |
| MAX | Maximum |
| MED | Median |
| MIN | Minimum |

# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| MOP | Minimum Operating Pool |
| MW | megawatts |
| n/a | Not Applicable |
| NMFS | National Marine Fisheries Service |
| NPPC | Northwest Power Planning Council |
| NWPP | Northwest Power Pool |
| O | reservoir outflow |
| PATH | Plan for Analyzing and Testing Hypotheses |
| PDR | Power Discharge Requirement |
| PNCA | Pacific Northwest Coordination Agreement |
| PNW | Pacific Northwest |
| RKM | River Kilometer |
| RM | River Mile |
| ROD | Record of Decision |
| SAM | System Analysis Model |
| SSARR | Streamflow Synthesis and Reservoir Regulation Model |
| URC | Upper Rule Curve |
| USFWS | U.S. Fish and Wildlife Service |
| VECC | Variable Energy Content Curve |
| WSCC | Western System Coordinating Council |

# Executive Summary

The hydroregulation workgroup has completed a preliminary analysis on the hydraulic response of the hydropower system for proposed alternatives for the Lower Snake River Juvenile Salmon Feasibility Study. The U.S. Army Corps of Engineers (Corps) funded a 2-year study for this workgroup to develop hydroregulation specifications for each measure under consideration, to perform the modeling, and to disseminate the modeling results to other workgroups. This analysis is still subject to changes based on further review comments.

Hydroregulations are sequential stream flow models that simulate the Columbia River Basin reservoir system under different operating requirements defined by the proposed alternatives. The hydroregulations provide a realistic monthly operation of facilities for each alternative under investigation.

Representatives of PATH (the Plan for Analyzing and Testing Hypotheses group examining salmon passage survival and life-cycle models) and other interested parties conceptually identified the alternatives and measures to be investigated by the hydroregulation modelers or hydroregulators. Below is a table showing which of the most significant operational measures were included in each alternative.

**Table ES-1.** Alternatives and Measures

| Alternative | Columbia River Flow Augmentation | Snake River Flow Augmentation | Upper Snake Flow Augmentation (KAF) | 4-Lower Snake River Dams at Natural River | John Day at Natural River | John Day at Spillway |
|---|---|---|---|---|---|---|
| A1 | Yes | Yes | 427 | No | No | No |
| A2* | Yes | Yes | 427 | No | No | No |
| A3 | Yes | Yes | 427 | Yes | No | No |
| A5 | Yes | No | 0 | Yes | No | No |
| A6a | Yes | Yes | 1,427 | No | No | No |
| A6b | Yes | Yes | 0 | No | No | No |
| B1 | Yes | Yes | 427 | Yes | Yes | No |
| B2 | No | No | 0 | Yes | Yes | No |
| C1 | Yes | Yes | 427 | Yes | No | Yes |
| C2 | No | No | 0 | Yes | No | Yes |

* A2 has no spill at Lower Granite, Little Goose, Lower Monumental and McNary.

Four alternatives were developed to assess John Day Dam operation at the natural river and spillway levels. These alternatives were used to illustrate the effect that different operating levels at John Day Dam would have on the Lower Snake River Juvenile Salmon Migration Feasibility Study. This study will not be used to make a decision regarding drawdown of the John Day Dam.

Hydroregulators representing different interests in the region met to discuss the methodology for modeling the alternatives and to develop the detailed hydroregulation specifications for each one. These specifications were reviewed by a broader agency, PATH, and an economic group before the modeling began.

Results from the hydroregulations were used by other work groups participating in the Lower Snake River Juvenile Salmon Migration Feasibility Study to determine the economic benefit of operating the system under the specified set of measures for each alternative. Outputs of the modeling include regulated steam flow, end-of-month elevations, tailwater elevations, spill, project generation, and system generation. The Hydropower Impact Team was one of the major users of the modeling results. They used the project and system generation in their production cost models to determine the costs for or impacts of meeting system load under each alternative. PATH used the regulated flow, etc., to elevate downstream survival.

A second model in the region was used to perform hydroregulation studies. The results from this modeling provided the region with another analysis tool. The two models generally matched, even though two different modeling procedures were used.

Breaching of the four Lower Snake River dams, Lower Granite, Little Goose, Lower Monumental, and Ice Harbor, would eliminate 3,033 megawatts of installed nameplate capacity. Eliminating this capacity would impact the system by removing the capability to generate 1,200 average megawatts of energy a year, based on a August 1, 1928, through July 31, 1989, historical streamflow record. The hydroregulation studies showed that some of the generation that would be lost by breaching these power generation facilities would likely be replaced by other projects in the Pacific Northwest.

# 1. Introduction

## 1.1 Scope

The hydroregulation work group is composed of representatives from the U.S. Corps of Engineers (Corps), Bonneville Power Administration (BPA), U.S. Bureau of Reclamation (BoR), National Marine Fisheries Services (NMFS), U.S. Fish and Wildlife Service (USFWS), Northwest Power Planning Council (NPPC), tribes, and states. This group was responsible for specifying the requirements and using the computer hydroregulation models to simulate the operation of the river system for all of the alternatives evaluated in the Lower Snake River Juvenile Salmon Migration Feasibility Study (Feasibility Study). These models are complex computer programs that sequentially route streamflows through each hydropower facility in the system, calculating the regulated stream flows, reservoir elevations, spill, power generation, and other information at each facility and pertinent control points in the Columbia River Basin. Hydroregulation specifications for each alternative were developed through numerous work group meetings. Each specification was reviewed to ensure that the system operation scenario could be adequately modeled to allow evaluation of each alternative. The specifications were then reviewed by a broader group that included, i.e., the Implementation Team, Plan for Analyzing and Testing Hypotheses (PATH), etc. After this wider review was completed the hydroregulations were run and results were summarized.

## 1.2 Study Process

The first step was to develop a hydroregulation specification for each alternative. These specifications were coordinated with the work groups and others to ensure that alternatives were described in sufficient detail to model the reservoir system under each scenario. The computer simulation results were then provided to work groups and other interested parties. Although the Corps and BPA performed the hydroregulation studies, all members of the hydropower group actively participated in reviewing the results prior to providing them to the other work groups. The hydroregulation results provided to other work groups consisted of project data such as average monthly flow, end-of-month elevation and other similar information, as well as system-wide data such as monthly energy generation.

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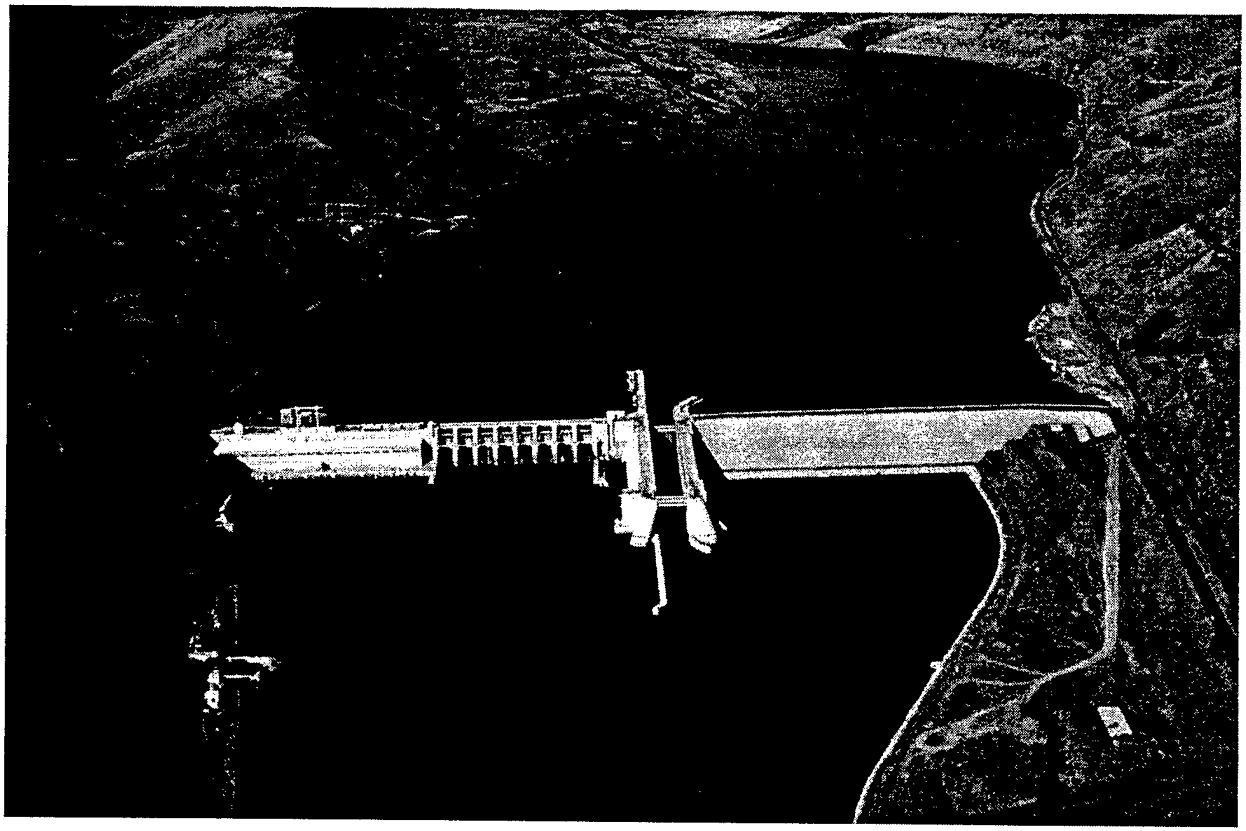
# 2. The Lower Snake River Hydropower Facilities



## 2.1 Lower Granite

### 2.1.1 Description

| | |
|---|---|
| Stream: | Snake River (173 RKM) (RM 107.5) |
| Location: | Almota, Washington |
| Owner: | U.S. Army Corps of Engineers,<br>Walla Walla District |
| Project Authorization: | PL 79-14, 1945 |
| Project Uses: | Power, Navigation, Fish and Wildlife, Recreation, Irrigation |
| Type of Project: | Run-of-river |
| Lake: | Lower Granite Lake |

### 2.1.2 Status and History

Lower Granite was authorized by PL 79-14 in accordance with a plan submitted in House Document 704, 75th Congress, 1945. The initial hydropower facility with units 1 through 3 was completed in 1975. The additional units, 4 through 6 were completed in 1978.

### 2.1.3 Lewiston Gage Elevation – m (ft)

Maximum pool ........ 231.6 (760.0)
Normal full pool ........ 224.9 (738.0)
Minimum pool ........ 223.4 (733.0)
Maximum elevation for flood control
July 15 - December 14 ........ 224.9 (738.0)
December 15 - March 14 ........ 224.6 (737.0)[1/]
March 15 - July 14 ........ 224.9 (737.7)[1/]

### 2.1.4 East Lewiston Gage Elevation –m (ft)

Full pool (150,000 cubic feet per second [cfs] in Clearwater at Spalding) ........ 226.9 (744.4)

### 2.1.5 Forebay Elevation – m (ft)

Maximum pool ........ 227.5 (746.5)
Normal full pool ........ 224.9 (738.0)
Normal minimum pool ........ 223.4 (733.0)
For flood control
Minimum for inflows of 250,000 cfs or greater ........ 220.7 (724.0)
Maximum for inflows of 120,000 cfs or greater ........ 223.7 (734.0)

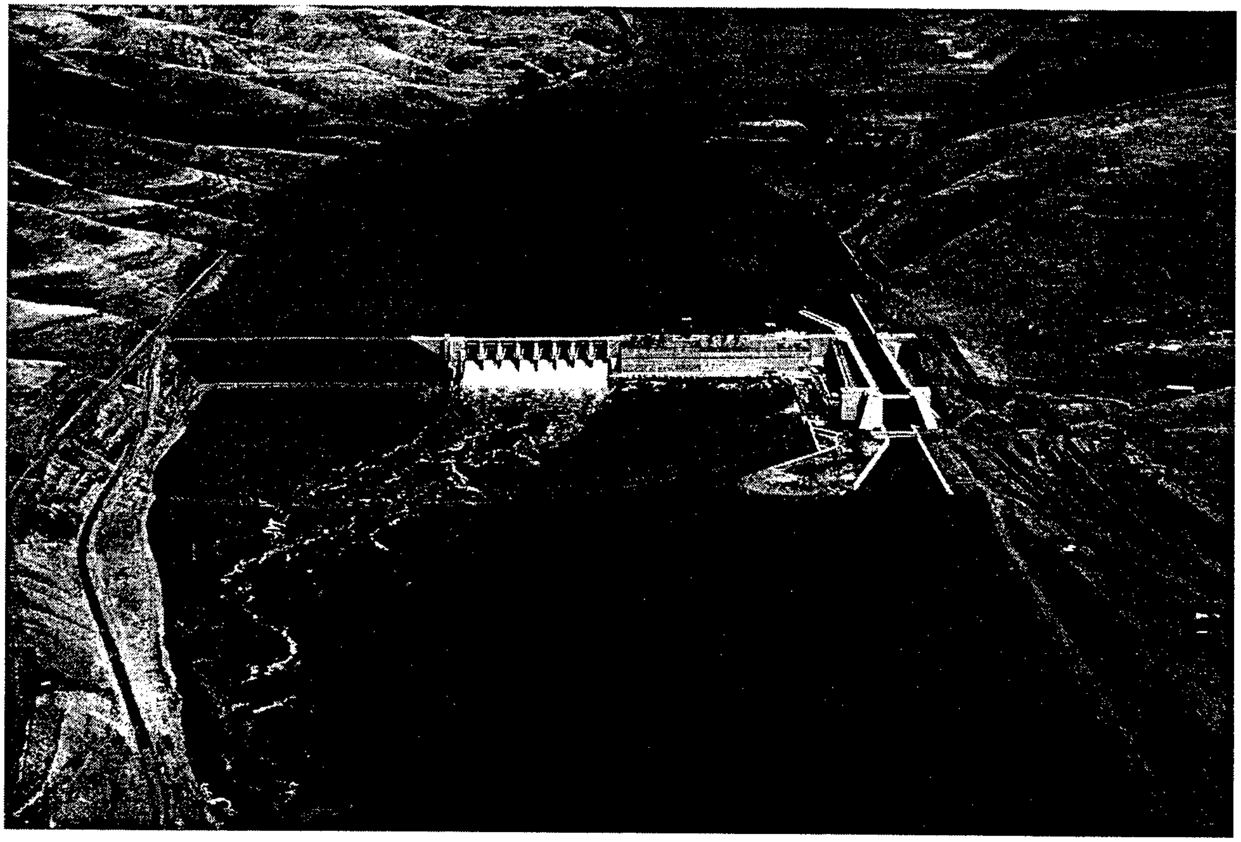
### 2.1.6 Discharge – $m^3/s$ (cfs)

Minimum
December-February ........ Zero
March-November ........ 325.6 (11,500)
Maximum rate of change per hour ........ 1,982.38 (70,000)

### 2.1.7 Powerhouse

Number of units ........ 6
Nameplate capacity (6 @ 135 megawatts [MW]) ........ 810 MW
Overload capacity (6 @ 155.3 MW) ........ 932 MW
Hydraulic capacity ........ 3,681.9 $m^3/s$ (130,000 cfs)

[1/] For inflows greater than 1,415.84 $m^3/s$ (50,000 cfs), otherwise maximum elevation is 224.94 m (738.0 ft).



## 2.2 Little Goose

### 2.2.1 Description

| | |
|---|---|
| Stream: | Snake River (112.7 RKM) (RM 70.3) |
| Location: | Starbuck, Washington |
| Owner: | U.S. Army Corps of Engineers, Walla Walla District |
| Project Authorization: | PL 79-14, 1945 |
| Project Uses: | Power, Navigation, Fish and Wildlife, Recreation, Irrigation |
| Type of Project: | Run-of-river |
| Lake: | Lake Bryan |

### 2.2.2 Status and History

Little Goose was authorized by PL 79-14 in accordance with a plan submitted in House Document 704, 75th Congress, 1945. The initial hydropower facility with units 1 through 3 was completed in 1970. The additional units 4 through 6 were completed in 1978.

### 2.2.3 Lake Elevation – m (ft)

Maximum pool ............ 197.1 (646.5)

Full pool ............ 194.5 (638.0)[1/]

Minimum pool ............ 192.9 (633.0)[1/]

### 2.2.4 Discharge – $m^3/s$ (cfs)

Minimum

December-February ............ Zero

March-November ............ 325.6 (11,500)

Maximum rate of change per hour ............ 1,982.2 (70,000)[2/]

### 2.2.5 Powerhouse

Number of units ............ 6

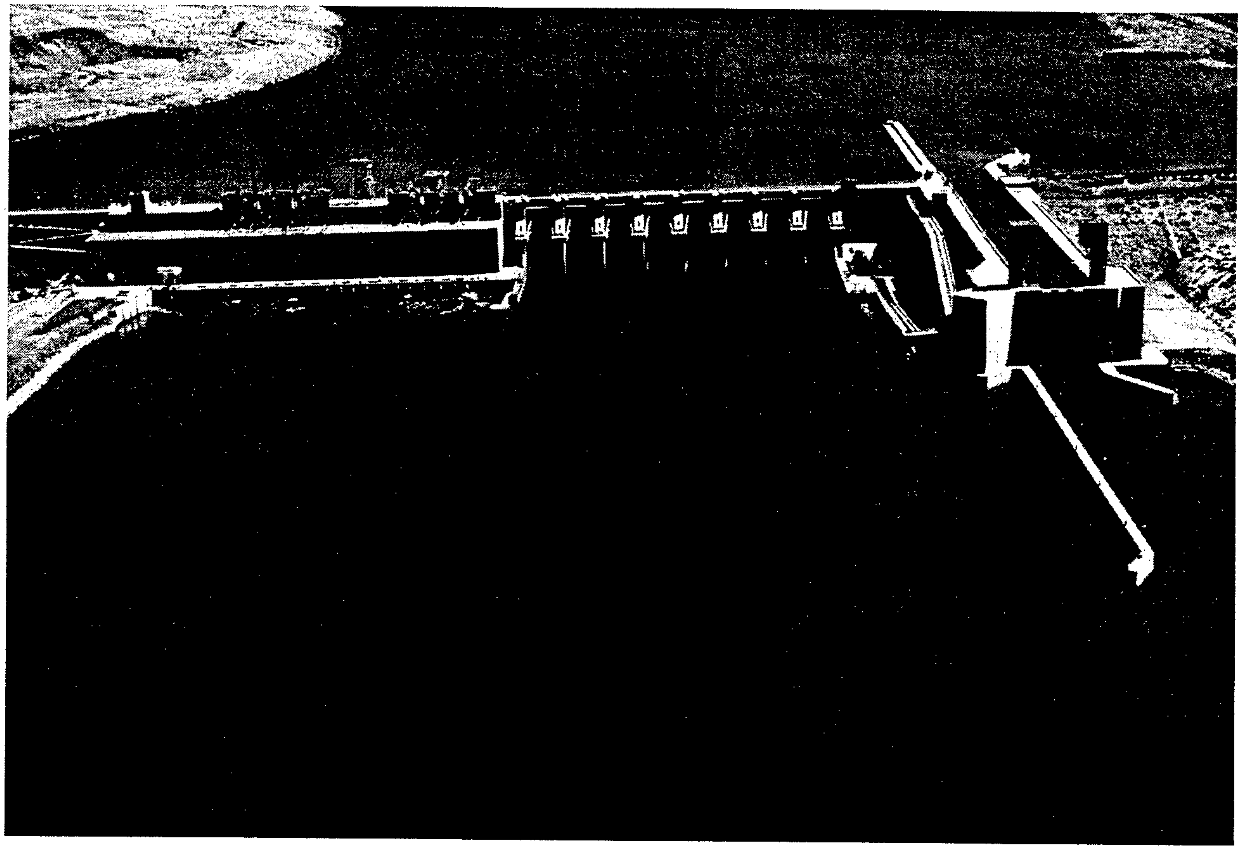
Nameplate capacity (6 @ 135 MW) ............ 810 MW

Overload capacity (6 @ 155.3 MW) ............ 932 MW

Hydraulic capacity ............ 3,681.2 $m^3/s$ (130,000 cfs)

---

[1/] Project Engineer can authorize lake to fill to elevation 194.6 m (638.5 ft) or draft to elevation 192.8 m (632.5 ft) to allow for unexpected events.
[2/] Based on 0.4572 m/hour (1.5 ft/hour) change.



## 2.3 Lower Monumental

### 2.3.1 Description

| | |
|---|---|
| Stream: | Snake River (66.9 RKM) (RM 41.6) |
| Location: | Matthaw, Washington |
| Owner: | U.S. Army Corps of Engineers,<br>Walla Walla District |
| Project Authorization: | PL 79-14, 1945 |
| Project Uses: | Power, Navigation, Fish and Wildlife, Recreation, Irrigation |
| Type of Project: | Run-of-river |
| Lake: | Lake Herbert G. West |

### 2.3.2 Status and History

Lower Monumental was authorized by PL 79-14 in accordance with a plan submitted in House Document 704, 75th Congress, 1945. The initial hydropower facility with units 1 through 3 was completed in 1970. The additional units, 4 through 6 were completed in 1978.

### 2.3.3 Lake Elevation – m (ft)

Maximum pool ........ 167.1 (548.3)

Normal pool ........ 164.6 (540.0)[1/]

Minimum pool ........ 163.7 (537.0)[1/]

### 2.3.4 Discharge - $m^3/s$ (cfs)

Minimum

December-February ........ Zero

March-November ........ 325.6 (11,500)

Maximum rate of change per hour ........ 1,982.2 (70,000)[2/]

2/ Based on 1.5 ft/hour change.

### 2.3.5 Powerhouse

Number of units ........ 6

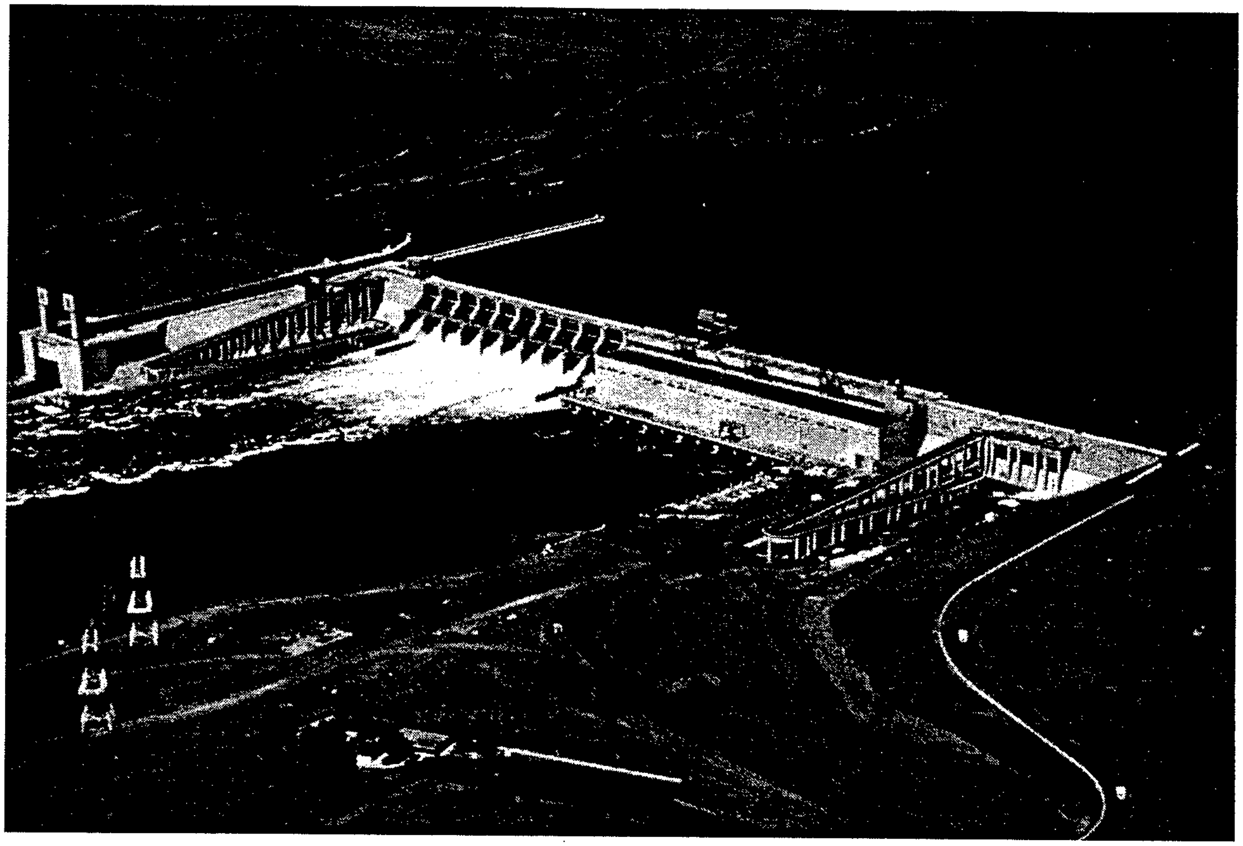
Nameplate capacity (6 @ 135 MW) ........ 810 MW

Overload capacity (6 @ 155 MW) ........ 930 MW

Hydraulic capacity ........ 3,681.2 $m^3/s$ (130,000 cfs)

---

[1/] Project Engineer can authorize lake to fill to elevation 164.7 m (540.5 ft) or draft to elevation 163.5 m (536.5 ft) to allow for unexpected events.
[2/] Based on 0.4572 m/hour (1.5 ft/hour) change.



## 2.4 Ice Harbor

### 2.4.1 Description

| | |
|---|---|
| Stream: | Snake River (15.6 RKM) (RM 9.7) |
| Location: | Pasco, Washington |
| Owner: | U.S. Army Corps of Engineers,<br>Walla Walla District |
| Project Authorization: | PL 79-14, 1945 |
| Project Uses: | Power, Navigation, Fish and Wildlife, Recreation, Irrigation |
| Type of Project: | Run-of-river |
| Lake: | Lake Sacajawea |

### 2.4.2 Status and History

Ice Harbor was authorized by PL 79-14 in accordance with a plan submitted in House Document 704, 75th Congress, 1945. The initial hydropower facility with units 1 through 3 was completed in 1962. The additional units 4 through 6 were completed in 1976.

### 2.4.3 Lake Elevation – m (ft)

Maximum pool ........ 135.9 (446.0)

Full pool ........ 134.1 (440.0)[1/]

Minimum pool ........ 133.2 (437.0)[1/]

### 2.4.4 Discharge – $m^3/s$ (cfs)

Minimum

December-February ........ Zero

March-July ........ 269.0 (9,500)

August-November ........ 212.4 (7,500)

Maximum rate of change per hour ........ 566.3 (20,000)

### 2.4.5 Powerhouse

Number of units ........ 6

Nameplate capacity (3 @ 90 MW, 3 @ 111 MW) ........ 603 MW

Overload capacity (3 @ 103.5 MW, 3 @ 127.5 MW) ........ 693 MW

Hydraulic capacity ........ 3,001.6 $m^3/s$ (106,000 cfs)

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[1/] Project Engineer may authorize lake level to fill 0.2 m (0.5 ft) above normal full pool or draft 0.2 m (0.5 feet) below minimum pool to allow for unexpected events.

# 3. Project Operating Limits

## 3.1 A Review of Hydroregulation Modeling

Water surges past the giant turbines and into the tailrace at Grand Coulee Dam. The tailwater below the dam rises, and the current swells as the Columbia River moves along its 1,931.2-km (1,200-mile) journey to the Pacific Ocean. Eighty km (50 miles) downstream at Chief Joseph Dam, operators will either hold back some of the flow or release it all on to Wells, Rocky Reach, Rock Island, Wanapum, and Priest Rapids dams.

From one project to the next, runoff from Canadian and Northwest snowfields makes its way down the river. Streamflows build and diminish, and reservoir elevations rise and fall as the water enters man-made lakes and is released through powerhouses and over spillways.

Hydroregulation—regulating water—is the process planners and operators use to make decisions about routing water through the series of hydropower projects in the Columbia River Basin. Those decisions are geared to make the most efficient use of the water in the river and its tributaries, and to meet multiple objectives—from controlling floods to irrigating crops to generating electricity. Regulating a system as complex as the Columbia River requires continuous planning and powerful tools.

Today, planning and regulation are processes assisted by automation. The tools of the trade are sophisticated computer programs that in a matter of minutes can calculate the river system's response to a variety of streamflow and operating conditions. The programs are also referred to as "models" because they model or simulate operations of the river system. From the data the models provide, analysts can estimate the system-wide impacts of projected operations.

This chapter describes the concept of hydroregulation modeling and how these computer models are used to determine flows, elevations, and other information for projects in the system from which environmental effects are estimated.

## 3.2 The Role of Models in Planning

### 3.2.1 Why We Need Computer Models

The Columbia River Basin covers 668,216.9 square km (258,000 square miles). The Columbia River and dozens of large tributaries drain this area, which extends from Canada to Nevada and from western Wyoming to the Pacific Ocean.

There are more than 150 dams and reservoirs on the coordinated river system—31 of them operated by Federal agencies—that work together to satisfy many needs. Hydroregulation models simulate how major projects in this system will react to changes in operations and to a wide range of runoff conditions. They also help plan how to use the water most efficiently.

Within the Columbia Basin, ten major river uses are considered: navigation, flood control, irrigation and water supply, electric power generation, anadromous fish migration, resident fish habitat, wildlife habitat, recreation, water quality, and protection of cultural and historical sites.

What happens at each project to meet one or more of these objectives has an effect on other projects, both upstream and downstream. Hydroregulation models enlarge the planners' ability to analyze how the variables interact when there is more or less water in the system and when operating changes are considered for any or all projects.

Calculations that would take weeks and months to complete by hand take minutes with a computer. The speed with which the computer processes data makes it possible to consider far more information and to make timely and precise adjustments to operations.

### 3.2.2 When Were the Models Developed?

Computer models have become so pervasive in the planning environment that it is hard to remember life without them. But in the 1930s, 40s, and 50s, when the hydropower system was smaller and less complex, hydroregulation was done using mechanical desk calculators and hand-drawn spreadsheets. This limited the amount of operating information that could be analyzed. Operations at each project were updated individually.

Hydroregulation models began to replace hand calculations in the late 1950s and early 1960s. The comprehensive planning models used today by the Corps and BPA have their roots in mainframe computer programs that were developed in the mid-1950s. The models continue to evolve as computer capabilities expand, precision in modeling increases, and river operations become more complicated.

### 3.2.3 The Columbia River Models

There are three primary hydroregulation models used today for medium- and long-term planning on the Columbia River: the Hydro System Seasonal Regulation Program (HYSSR), the Hydro Simulator Program (HYDROSIM), and the Pacific Northwest Coordination Agreement Seasonal Regulation Program (HYDREG).

On a conceptual level, the models are almost identical, except for the determination of energy and capacity. HYSSR uses characteristics of the operating unit to determine the efficiency in the hydropower equation. HYDROSIM and HYDREG use a range of head-to-kilowatt ratios to determine the energy and capacity. Since the agencies that designed and use them have distinct missions, each does have a unique point-of-view. The models were developed independently and are used to perform studies based on specific agency and constituent needs. Information and expertise is often shared among the agencies and the analysts, and in some instances, one model produces data that is used for studies run on another model.

HYSSR is the oldest of the three models. It has its genesis in a model developed by the Corps for its 1958 comprehensive system planning study. HYSSR simulates the characteristics of the Northwest hydropower system under varying electric energy requirement (load) and streamflow conditions, over an extended period of time.

HYDROSIM was developed by BPA in 1990 and 1991. It evolved from earlier programs called HYDRO2 and HYDRO6, which were written in the 1960s. Like HYSSR, HYDROSIM simulates the operating characteristics of the Northwest hydropower system under varying load and flow conditions, over an extended period of time.

HYDREG was originally developed in the 1960s at BPA, but it is now maintained and operated by the Northwest Power Pool (NWPP). HYDREG is used to establish seasonal guidelines for coordinated operation of hydro projects included in the Pacific Northwest Coordination Agreement (PNCA). The guidelines maximize power benefits while satisfying multiple non-power uses of the river system.

## 3.3 The Basics of Streamflow Routing

### 3.3.1 The Continuity Equation

Hydroregulation models are sequential streamflow routing models. At the heart of each model is the same calculation. It is called the continuity equation, and it goes like this:

The average reservoir outflow (O) in any time period is equal to the average reservoir inflow (I) during the same period minus the change in reservoir storage (ΔS) minus the losses (L).

Put another way, $O = I - \Delta S - L$.

For each dam in the system in a given time period, the program calculates what the outflow would be given:

- the inflow (from natural runoff and releases from any upstream projects),
- the change in storage at that dam (ΔS is positive if water is added to storage; ΔS is negative if water is released from storage), and
- losses (from diversions, withdrawals, or evaporation).

In many cases, the objective of system operation is to provide a particular flow on a river reach for navigation, fish passage, or power generation. The problem then is to determine how storage must change in the reservoir to ensure that this flow requirement is met. In such cases, the continuity equation would be set up and solved as follows:

$$\Delta S = I - O - L.$$

The calculation in this instance determines the change in storage given inflow, outflow, and losses. The model repeats the continuity equation for each project considered and for each time period in an analysis. The model calculates this information sequentially in time. In a full system analysis, the computation starts with the uppermost storage reservoir on the system. The outflow at the first project, plus or minus any major changes along the way, such as an irrigation diversion or the confluence with a tributary, becomes the inflow at the next project. And so the model continues, calculating the streamflows and reservoir elevations for the time period at every project on the system.

### 3.3.2 Using the Models to Meet Objectives

Hydroregulation models can be used to help determine how to meet a variety of operating objectives. For example, one of the objectives on the Columbia River System is power generation. The models first compute the outflow at each dam. Using another set of equations, the outflow can be converted to electrical power production in megawatts (MW).

Energy generation relies on project flows. The amount of power produced depends on three factors:

1. How much water flows through the turbines, usually measured in cubic meters per second ($m^3/s$) [cubic feet per second (cfs)].

2. The vertical distance the water falls, called "head." This is the difference between the height of the water behind the dam (forebay elevation) and the height of the water below the dam (tailwater elevation) measured in meters (feet).

3. The efficiency of the generating equipment. Hydropower project efficiencies generally range from 85 to 95 percent.

The equation for calculating how much power can be generated at a project is:

$$\text{Power (KW)} = \frac{\text{Flow (cfs)} \times \text{Head (ft)} \times \text{Efficiency (\%)}}{11.8}$$

$$P = \frac{Q \times H \times E}{11.8}$$

As an example: Power from 100,000 cfs of water flowing through Grand Coulee at full pool (El 1,290 ft) would be calculated as follows:

Tailwater = 962 ft at 100,000 cfs discharge

Head = 1290 - 962 = 328 ft

Efficiency = 88 %

$$\text{so, } P = \frac{100{,}000 \times 328 \times 0.88}{11.8} = 2{,}450{,}000 \text{ KW} = 2{,}450 \text{ MW}$$

Once the conversion to power is made, the model adds up the power generation in MWs determined for all of the projects. The result is a figure that represents the system-wide power output in MWs.

Flood control is another key objective in Columbia River operations. Maximum flows, above which flooding will occur, have been established at key points on the river. Streamflow routing models can help determine how much water must be stored in the reservoirs during flood periods so that keypoints in the rivers will be kept below flood levels.

At Vancouver, Washington, for instance, flows that exceed 16,990.1 $m^3/s$ (600,000 cfs) will cause minor flood damages and flows that exceed 21,237.6 $m^3/s$ (750,000 cfs) will cause major damages. A model can demonstrate whether planned operations upriver can contain the water or whether the maximum flow at Vancouver will be exceeded.

Hydroregulation models can be used to assess whether planned operations will provide flows adequate to protect fish and wildlife habitat at various places on the river and to move juvenile salmon to the ocean. For example, the 1995 Biological Opinion aims to achieve a minimum flow objective during the spring and summer at McNary Dam on the Columbia River and at Lower Granite Dam on the Snake River. This helps fish move more quickly between projects. The models

are used to determine how much water must be released from storage projects to ensure that these flow objectives are met.

On a complex river system such as the Columbia, where there are numerous competing river uses, streamflow routing models help in planning operations that attempt to satisfy a combination of objectives at the same time. The three models discussed in this chapter consider all system uses simultaneously.

### 3.3.3 Control Points

The previous discussion touched on an essential part of the streamflow routing models—control points. Control points are identified and characterized in the models. They are points on the river where streamflow or elevation targets or both have been established and where they are measured or gauged. In the Columbia River system models, all of the run-of-river dams and storage reservoirs are control points.

There are other control points on the system where flow or elevation targets have been established to meet a particular need. At Vernita Bar on the mid-Columbia River, for example, a seasonal flow target protects chinook salmon spawning grounds. Releases from Hells Canyon Dam are made to keep an adequate navigation depth on the Snake River downstream at Lime Point, another example of a control point. And, as noted earlier, Vancouver, Washington, is the control point used to gage flood control operations to protect the highly developed areas along the lower Columbia River.

Given an operating scenario, the models attempt to operate the reservoir system to meet the specified objectives, and they report elevations and/or streamflows at each control point. If the computer output shows that a certain operation will not meet the objectives at one or more points, adjustments to the operating criteria may be made to bring outcomes closer. For example, more water may be held upriver if the elevation at a downstream control point is too high. Additional water may be released from a reservoir if the flow at a downstream control point is too low.

It should be noted, however, that at times not all of the targets could be met simultaneously. The models have built-in priority lists (which can be changed if necessary) for which some targets take precedence over others at a given control point. For example, flood control objectives always take precedence over hydropower requirements. This topic appears again in Section 3.6 where specific types of model runs are described. Table 3-1 provides a list of projects and control points for which data are output from the hydroregulation models in a full-scale analysis.

## 3.4 The Model Inputs

A product is only as good as the parts that go into it. Therefore, the output of the hydroregulation models is only as up-to-date and accurate as the data that are input. The models themselves can be run in a matter of minutes. Preparing the data for a run can take weeks.

Hydroregulation models are general-purpose models, designed to be driven by the data. Each model is basically a suite of programs. The "hydroregulator" is the centerpiece of the models and consists of 20 to 30 subroutines. As many as 20 ancillary programs prepare data files that are used by the hydroregulation models. The key pieces of input data are described below. Much of the data for each model are stored as tables and graphs in master project files.

**Table 3-1.** Hydroregulation Output Data Locations

| Name | Location |
|---|---|
| Mica | Columbia River, British Columbia, Canada |
| Arrow | Columbia River, Castlegar, British Columbia |
| Libby | Kootenai River, Libby, Montana |
| Bonners Ferry | Kootenai River, Bonners Ferry, Montana |
| Duncan | Columbia River, British Columbia, Canada |
| Corra Linn | Columbia River, Nelson, British Columbia |
| Brilliant | Columbia River, Castlegar, British Columbia |
| Hungry Horse | Flathead River, Hungry Horse, Montana |
| Columbia Falls | Flathead River, Columbia Falls, Montana |
| Kerr | Flathead River, Polson, Montana |
| Albeni Falls | Pend Oreille River, Newport, Washington |
| Grand Coulee | Columbia River, Grand Coulee, Washington |
| Chief Joseph | Columbia River, Bridgeport, Washington |
| Wells | Columbia River, Azwell, Washington |
| Rocky Reach | Columbia River, Wenatchee, Washington |
| Rock Island | Columbia River, Wenatchee, Washington |
| Wanapum | Columbia River, Ephrata, Washington |
| Priest Rapids | Columbia River, Ephrata, Washington |
| Brownlee | Snake River, Cambridge, Idaho |
| Dworshak | Snake River, Ahsahka, Idaho |
| Spalding | Snake River, Spalding, Idaho |
| Lower Granite | Snake River, Almota, Washington |
| Little Goose | Snake River, Starbuck, Washington |
| Lower Monumental | Snake River, Matthaw, Washington |
| Ice Harbor | Snake River, Pasco, Washington |
| McNary | Columbia River, Umatilla, Oregon |
| John Day | Columbia River, Rufus, Oregon |
| The Dalles | Columbia River, The Dalles, Oregon |
| Bonneville | Columbia River, Bonneville, Oregon |

### 3.4.1 Streamflow Records

Streamflow records are the backbone of the hydroregulation studies. These records are essentially the unregulated flow of water at various points in the system. The Columbia River hydroregulation models currently have a 60-year historical streamflow record, 1928 to 1989. (The record is periodically extended, and 10 more years will soon be added.) The streamflow measurements recorded for these years are adjusted to account for storage change, evaporation, and irrigation

depletions since they were gathered. The adjustments are made to simulate natural streamflows as closely as possible and to put the entire set of streamflows on a common base.

For example, the irrigation system in the region was developed gradually. Measurements taken in 1928 at any control point on the river would not reflect the level of irrigation depletions that now take place. The records are adjusted on a 10-year cycle to recognize current conditions. They also reflect current operation of tributary reservoirs that are not modeled in the hydroregulator, such as those in the upper Snake, Yakima, and Deschutes basins. In essence, the model simulates what would happen on today's river system given the precipitation and weather conditions that actually occurred in 1928. The source for the current streamflow data is the Columbia River Water Management Group's publication, *1990 Level Modified Streamflow*, dated July 1993.

### 3.4.2 Project Characteristics

The models also incorporate the physical characteristics of the projects in the Columbia River System. These include minimum and maximum reservoir elevations, storage-elevation relationships, tailwater elevations, and power plant characteristics.

The number of projects for which this information is included varies among the models. Normally, it can change with the particular study or operation being simulated. HYSSR and HYDROSIM use 80, but they also performs studies that use only 36. The HYDREG, includes the largest number of projects of 150.

### 3.4.3 Project Operating Requirements

Operating requirements are the power production and non-power requirements that define a project's operation. These include the maximum and minimum amount of water that can be released from a project at one time (discharge), and the maximum and minimum reservoir volume content. These requirements may serve to protect areas downstream from a project. For example, a large instantaneous release could endanger fish spawning grounds below a dam. Requirements may also aim to preserve resources at a reservoir, e.g., when water is drawn down too low, resident fish and shoreline vegetation suffer.

Many operating requirements are seasonal. For example, to keep rivers from overflowing their banks during the high runoff period, reservoirs must be drawn down before the middle of April in anticipation of the spring snowmelt. Reservoir elevations are allowed to go higher in July, when the danger of flooding is gone, and vacationers want a full lake for boating. Tables in the model incorporate these seasonal variations. Normally, operating requirements are specified by the project owners and submitted to the NWPP for PNCA planning.

### 3.4.4 System Power Loads

Hydroregulation models are used to compute the system's ability to meet electricity loads (the amount of power that customers of the power system need at any given time) in the Northwest and to determine how much electricity to sell outside the region. Electricity loads are input to the models. Different hydroregulatory studies answer different questions: Is the system capable of meeting the projected load? How much power can be generated under a given set of operating conditions? Will thermal generation be needed in addition to hydropower generation to meet the loads? If so, how much?

### 3.4.5 Thermal Resources

The models may incorporate other non-hydropower, thermal power-generating resources, such as coal and nuclear (thermal) plants, as part of the computation in certain studies. The ability of these resources to contribute to the region's power supply is a consideration in determining how and whether the region's generating resources can meet current and future loads. Thermal plant operation affects the regulations for reservoirs in the coordinated system.

### 3.4.6 Rule Curves

Rule curves represent seasonal reservoir water level objectives and provide guidance in meeting project purposes. In some cases, the curves set elevations that must be met in each time period. At other times, they specify upper or lower elevations that are not to be violated. There are also occasions when rule curves define a range over which operations are permitted. Rule curves can be a product of the hydroregulation models, and they can be used as input data to determine reservoir operations.

The operating year on the Columbia River System is August 1 through July 31. Before each new operating year, studies are made using the hydroregulation models and historical streamflow records to derive the rule curves for multipurpose operation of the dams on the river. The models then use the rule curves to predict how much energy could be produced during the coming year under differing water conditions.

### 3.4.7 Ranges of Requirements

One valuable use of the hydroregulation models is to test ranges of operating requirements to evaluate their impact on project power outputs and other river uses. For example, possible operating scenarios may be established to compare current operations with a hypothetical or future situation. The models will compute and report the flows and elevations that would result from a number of operational changes. This use of the models is essential in the Feasibility Study. They provide the basis for determining how operating changes affect the multiple river uses.

### 3.4.8 Where Do Input Data Come From?

There are long-established means for collecting and preparing the input data needed for the models. The data fall roughly into three categories:

- Data that are permanent
- Data that are revised annually
- Data that are revised only as needed.

Many model input data do not change over the years in a study period. In general, these are the physical characteristics of hydropower projects. Load and critical rule curves, on the other hand, are updated frequently. Appropriate revisions are made to reflect such things as current lists of resources and operating requirements. Data that are revised only as needed include such things as non-power operating requirements. If a new requirement is established, the information goes into the input program files. For example, in 1995, when fish-related flow objectives were established at McNary and Lower Granite, these were entered into the input data files.

Some data come from other government agencies. The U.S. Geological Survey collects streamflow measurements; the Natural Resources Conservation Service calculates snowpack; and the National Weather Service, Northwest River Forecast Center, develops streamflow (volume) forecasts.

As described previously, with rule curves, the output of one hydroregulation model becomes the input for another, or for a new computational run with the same model. HYDROSIM calculates rule curves that are used in many studies elsewhere, and both HYSSR and HYDROSIM are used to develop new operating requirements that are input into HYDREG in developing rule curves under the PNCA.

## 3.5 A Closeup of the Columbia River Models

The hydroregulation models are similar in many ways. They are all sequential streamflow routing models that simulate the same basic physics, the continuity equation. Each operates over a year that is divided into 14 periods. Each month is a period identified with the three letters capitalized. April and August are divided into two periods because stream flows vary greatly from the first half to the second half of these months. April 1-15 is identified as APR 1, April 16-30 is identified as APR 2, August 1-15 is identified as AUG 1 and August 16-31 is identified as AUG 2. So, the 14 periods from 1 August through 31 July are AUG 1, AUG 2, SEP, OCT, NOV, DEC, JAN, FEB, MAR, APR 1, APR 2, MAY, JUN and JUL.

All three models are written in a computer language called FORTRAN. The models all assume that water released at the uppermost project on the river during a specific period will reach the ocean during the same period, if not retained in storage downstream.

### 3.5.1 Hydro System Seasonal Regulation Program (HYSSR)

HYSSR is the oldest model in the region and has been updated with all current logic. It was written to analyze the Columbia River System, and is capable of simulating the region's hydropower and flood control operations as they are to be carried out under terms of the Columbia River Treaty between the United States and Canada, and the PNCA. It also accounts for all other non-power operating requirements.

The Corps uses a separate model called Streamflow Synthesis and Reservoir Regulation (SSARR) for its flood control operations and daily river forecasting. (SSARR also develops the flood control rule curves used in the three hydroregulation models.)

HYSSR can be used in one of several single-objective modes or in a combination of modes. For example, in the "Fixed Rule-Curve Level" mode, the user specifies the rule curve to which each storage project will be operated. There are seven rule curves from which to choose: the flood control (upper) rule curve; the energy content curve; the first, second, third, or fourth year critical rule curves; and empty. Flows and power generation are computed based on the rule curve specified.

HYSSR is often used to model target flows. In the "Meet Target Stream Flows" mode, the user specifies the target streamflows at control points on the river, along with the reservoirs that are to be used for flow augmentation. The model will attempt to meet these targets, starting at the uppermost control point in the basin and proceeding downstream. Selected storage projects upstream of a control point will be drafted proportionately to meet the desired target.

In all modes, the model checks the operating requirements at each project. That means the model is programmed to look at all operating limits and alert the user if a simulation shows operations would be outside those bounds.

HYSSR is used to support several annual studies, including the region's reservoir refill studies. The PNCA planning goal is to generate secondary energy only to the extent that there is a 95 percent confidence those reservoirs will refill. Analysts use HYSSR to determine whether planned operations will meet that goal in any given operating year by running simulations that span the 60 years of streamflow records.

Other studies for which HYSSR is used include: modification of flood control operations, analysis of major rehabilitation of projects, evaluation of the potential impacts of revised irrigation depletion levels, and Endangered Species Act (ESA) consultation modeling.

### 3.5.2 Hydro Simulator Model (HYDROSIM)

HYDROSIM was written to replace two of BPA's earlier hydroregulation programs that could not share data with some of the agency's new power marketing and economic models, in particular the System Analysis Model (SAM). HYDROSIM incorporated the hydroregulation code used in SAM so data files can be easily interchanged between the models.

HYDROSIM models operations of the Pacific Northwest hydropower system. HYDROSIM can be used to determine critical rule curves and the availability of firm energy, or to examine operations under other historical streamflow conditions.

In its "Proportional Draft" mode, HYDROSIM simulates operations of the reservoirs under the PNCA. The program begins the simulation by drawing system reservoirs down to energy content curves. (This curve defines rights and obligations that the reservoir owner and downstream projects have for the use of storage under the PNCA.) Typically, water below the "firm drafting rights" elevation cannot be used. However, if the simulated system is unable to meet the system's firm load, a user option allows all reservoirs to be drafted through the critical rule curves until the firm load is met, or until the coordinated system goes empty or meets other limiting constraints.

Critical period planning is required by the PNCA. The critical period is the portion of the historical 60-year streamflow record that would produce the least amount of energy, with all reservoirs drafted from full to empty. This energy value is called the hydropower system's Firm Energy Load Carrying Capability (FELCC). The hydroregulation computer studies produce rule curves that define reservoir elevations that must be maintained to ensure firm energy requirements can be met under the most adverse historical streamflow conditions.

In recent years, the critical period has been based on the 42-month interval from September 1, 1936, through February 29, 1937. This is often referred to as the 4-year critical period. A critical rule curve is derived for each year of the 4 years; they are called Critical Rule Curves 1, 2, 3, and 4.

In HYDROSIM'S "Fixed" mode, each period's operation for all or some of the reservoirs is specified in advance by the modeler. Storage at each reservoir will be drafted or filled as specified (unless constrained by physical or operational limits). The program begins at the most upstream project and proceeds downstream, setting operation at each plant based on the user-specified operating mode. After the operation is set, the program calculates flows and resulting energy generation.

Most studies use a combination of fixed mode and proportional draft. Some projects are fixed, and others are free to draft among rule curves.

### 3.5.3 PNCA Hydro Regulator Model (HYDREG)

The NWPP model sets the regulations for coordinated operation of the region's hydroelectric system. HYDREG takes the individual operating rights and requirements from the region's project owners and blends them into an operating regimen known as the Actual Energy Regulation (AER).

HYDREG was written to guide the coordinated operation of the Northwest hydropower system as directed by the PNCA. It aims to optimize power production while fulfilling all project and system non-power requirements. It is run as often as weekly during the course of the operating year to produce the AER.

The AER determines the energy capability of each project, each party to the PNCA, and of the coordinated system as a whole. The AER also provides the draft point at each reservoir that serves as the basis for rights and obligations among upstream and downstream parties during actual operations.

There are three components or processes in the model. The driving function is to regulate the reservoirs; that is, to determine the desired reservoir contents at the end of each of the 14 periods, based on reservoir rule curves and power loads. (HYDREG reports reservoir contents, which are derived from elevations.) The second process simulates the operation of individual projects. This process successively operates each hydropower plant and calculates discharge and forebay elevations, and flow reductions for fish spill and bypass. A third process computes the energy generation and peak capability at each hydropower project.

HYDREG supports many studies in the region. It is used to develop the NWPP Operating Program for the PNCA members and for the Pool as a whole. (Not all utilities in the Pool are parties to the PNCA.) It calculates the FELCC for the coordinated system and for each utility within the system, and it determines what are known as "headwater benefits," the payments downstream beneficiaries make to storage project owners. HYDREG also calculates each party's interchange rights and obligations under the PNCA. These are sales and exchanges among utilities that keep the coordinated system operating most efficiently.

## 3.6 From Data to Decisions

The output of a hydroregulation model is numbers. There are streamflows, expressed in $m^3/s$ (cfs); reservoir elevations, given as feet above mean sea level (msl); reservoir contents, represented in either khm [thousand acre feet (KAF)] or khm [thousand second-foot days (ksfd)]; power generation in MW; and spill, expressed in $m^3/s$ (cfs). Data are presented by project and for the total system.

In general, there are three types of studies: continuous, refill, and critical period. Each of these studies answers a different kind of question or set of questions about system operations.

### 3.6.1 The Continuous Study

The continuous study gives planners an opportunity to look at what would happen on today's system of hydropower projects under a typical long-term sequence of streamflow conditions, such as the 60-year historical period from August 1928 to July 1989. The model begins its simulation on

August 1, 1928, with all reservoirs at predetermined elevations and with a prescribed set of rule curves or operating criteria for the upcoming year. It then sequentially calculates the flows and reservoir elevations that would result for each project on the river for each period in that year.

At the end of the 12-month (14-period) calculation, the study continues, modeling system operations using the July 31, 1929, reservoir elevations to begin the subsequent operating year. And so the analysis goes over 60 years, with the final elevations at the end of each operating year becoming the starting elevations for the upcoming year. This is the type of study used to determine the critical period, which is the sequence of months in the historical streamflow records that would produce the least water for power generation.

### 3.6.1.1 Adjusting Operations

A primary use of the continuous study is to determine the impacts of a specific operating change. For example, a proposal may be made to keep a certain reservoir full for an extra month during each year to lengthen the recreation season. Instead of drawdown beginning in September, it would begin in October. A continuous study can be run to simulate how that change in operation would affect streamflows and elevations at other projects on the river over a 60-year period. The study will yield data that can be used to demonstrate the types and magnitude of impacts that delaying drawdown at this project would have on other aspects of the hydropower system.

With this long-term view, planners are able to determine whether an operating change that looks feasible in the first 2 or 3 years has a fatal flaw at some point in the future. A set of operations geared to meet a particular flow objective might not strain the system in the first or second year. But analysis of a 60-year continuous study could show that in 5, 6, or 10 years, storage reservoirs are depleted, leaving boat ramps and recreation areas stranded, crops withering in dry fields, and electrical energy production greatly reduced.

### 3.6.1.2 Evaluating Resources

A continuous study can also help judge if and where to install a new hydropower generating unit. A computer run is made for a "base condition," that is, the way the system operates without the proposed generator. Then a run is made that includes the new unit. With 60 years of operation simulated by computer, planners can determine how much energy the new generator could be expected to produce and whether historical water conditions suggest the installation would be viable.

The analysis will also show whether the addition of the new project will increase the FELCC output of other projects in the system, which could be the case if the new project has seasonal storage. Additional studies can be made with varying dam heights, more or fewer generating units, or different project locations to see where it would be of the most benefit.

The continuous study can help to point out the tradeoffs that exist with any new operating scenario on a multi-use system. And it is a mechanism to test a potential operating decision. If boaters on one lake have a longer season, what would this mean next spring for fish downstream? Would a boost in flow help this year's migrating fish at the expense of the smolts 5 years from now? If BPA sells a large quantity of secondary energy next year, will there be enough power to meet firm loads in the following year?

The continuous study also provides information to answer economic questions. If a new generator is installed at an existing powerhouse on the lower Columbia, how much water can be anticipated to

fuel its operation? How much power would be available for sale? What percentage of the time could it be expected to operate efficiently given historical water conditions? These are real-life questions the region's power planners and water managers grapple with continually, and the computer simulations help provide the flows and elevations to assess these questions.

### 3.6.2 The Refill (Non-Continuous) Study

Using historical streamflow records, hydroregulation models simulate the likelihood reservoirs will refill over a year of operations. Refill is important for a number of reasons, but in particular, it is the region's hedge against dry years in the future. The amount of snow and rainfall is anybody's guess before winter begins, so it is prudent to have as much water on hand in the reservoirs as possible.

The 60-year refill study is actually 60 separate one-year studies. The reservoirs are set at the beginning of the study, August 1, 1928, to the elevations shown in the AER for July 31 of the preceding operating year. Operations are then simulated using the 1928-29 streamflow record. The reservoirs are reset to the same elevation again at the beginning of the next year in the historical sequence (the 1929-30 streamflow record). The simulation is repeated, using the historical streamflow records for each of the remaining 58 years. This gives planners the opportunity to look at how 60 different water conditions would play out on today's Columbia River hydropower system.

A non-continuous refill study can also be conducted with the elevations set at some level other than full. For example, a study may be run at mid-year to test the refill probability through the rest of the operating year. The beginning elevation is set to match the way a project has actually been operated during the first part of the year. The simulation tests 60 different historical streamflow sequences for the remainder of the year.

Under the PNCA, system operations are planned so there is an acceptable probability reservoirs will refill. The Corps uses its HYSSR model to run the annual 60-year PNCA Refill Regulation to assure that the operating rule curves developed under the PNCA have a 95 percent probability of refilling reservoirs by July 31. This refill regulation evaluates July 31 refill based on both full and observing the salmon Biological Opinion end-of-August draft limits.

The Refill Regulation is used to verify that PNCA operations have an acceptable probability of refill, and it is used to devise future operating rule curves. From the test, the Corps calculates the Assured Refill Curve for the following year. This curve will guide operations during the fixed drawdown period (late summer and fall) when the volume of the next spring runoff is unknown.

While refill is the primary use of this study, there are other uses for the non-continuous analysis. Since the reservoirs start each contract year at the same level, it is a way to examine 60 individual water years for many purposes, such as projecting the amount of energy that could be produced given the current level of system reservoirs.

### 3.6.3 The Critical Period Study

Critical period planning defines how much hydropower system energy should be considered firm. Hydroregulation models are used to generate the rule curves, which govern critical period operations, and to define FELCC of the system. These types of studies are run in continuous mode.

The NWPP uses HYDREG to determine the critical period rule curves and FELCC that are used to operate the system under the PNCA. BPA uses HYDROSIM for critical period studies to plan

resource acquisitions and to determine the United States' benefits from Canadian Treaty reservoirs. Some of this data also goes into calculating rates and projecting revenues.

The critical rule curves are developed by simulating system operations using the streamflows that were available in the 42-month period from September 1928 to February 1932. This calculation also yields the system's FELCC, that is, how much energy the coordinated system can be expected to generate under these adverse streamflow conditions. The NWPP's hydroregulation allocates FELCC to the members of the PNCA, according to the projects they own and operate, and based on other contract provisions. In recent years the PNCA studies indicate that the critical period has changed to the sequence from September 1936 to April 1937.

In a critical period study, the model takes the initial storage content (full) for each reservoir and simulates the operation for each period through the first operating year, using 1928-29 water. The reservoir content at the end of the first operating year is the beginning content for the next year, and so forth. A critical rule curve is plotted using the end-of-period reservoir content numbers. This first critical rule curve is known as Critical Rule Curve (CRC) 1.

The reservoir content at the end of the first year of the critical period becomes the beginning content for the second year. The model simulates another year of operations, and the reservoir contents at the end of the 14 periods are plotted as CRC2. The study continues through the 42-month critical period. The final result is four critical rule curves. CRC4 will indicate that all reservoirs are empty at the end of the critical period, February 1932.

Planners determine how much power can be generated if all of the reservoirs are drafted to CRC1, CRC2, CRC3, and CRC4, by converting the plant discharge to megawatts. This type of study is particularly important for BPA in determining how much firm and secondary energy can be produced and sold from the Federal hydropower system.

Critical period planning is premised on unusually low water conditions. During most years, there is more water in the system than the critical rule curves reflect. Consequently, BPA runs analyses that look at many ways to take advantage of water conditions that are more likely to occur.

### 3.6.4 Modeling Alternative Measures

All of the hydroregulation models' data can be modified, using variables in almost infinite combinations, to create different operating scenarios. For example, load growth can be held constant in a long-term analysis or a study can be run using a low-, medium-, or high-growth forecast. In some studies, a project or group of projects might be input as having a fixed operation in order to determine how the rest of the hydropower system would compensate. These variations in operating strategy usually do not mean changing the program, but mostly only require input data changes. The models are designed to accommodate them effectively.

# 4. Alternative Descriptions

## 4.1 General

### 4.1.1 General Description of Alternatives

This study investigated drawing down the four lower Snake River dams with different Columbia River and Snake River flow augmentation scenarios. The four dams are Lower Granite, Little Goose, Lower Monumental, and Ice Harbor. These measures are denoted as the "A" series of alternatives. In these alternatives Libby would still provide higher outflows for sturgeon. Below and in Table 4-1 is a brief description of these alternatives followed by the detailed hydroregulation specification beginning in Section 4.2.

- The Base Condition or Alternative **A1** is a continuous study of the system operations under the Salmon and Sturgeon Biological Opinion.
- Alternative **A2** is a continuous study of the system operations under the Salmon and Sturgeon Biological Opinion without drawdown on the lower Snake River or John Day reservoirs. This alternative relies on fish transportation as the primary method for fish passage and assumes the current level of development of fish facilities. Also, this alternative eliminates fish spill at fish transportation dams—Lower Granite, Little Goose, Lower Monumental, and McNary.
- Alternative **A3** is a continuous study of the system operations under a scenario where the Base Condition is adjusted for the drawdown of all four lower Snake River dams to natural river levels. Columbia River and Snake River flow augmentation would remain unchanged.
- Alternative **A5** is a continuous study of the system operations under a scenario where the Base Condition is adjusted for the drawdown of all four lower Snake River dams to natural river level and to remove flow augmentation on the lower Snake River at Lower Granite including the 52.7 khm (427 KAF) from the upper Snake River.
- Alternative **A6a** is a continuous study of the system operation under a scenario where the Base Condition is adjusted to increase the upper Snake River flow augmentation 123.3 khm [1 million-acre-feet (MAF)], to 176 khm (1,427 KAF) total upper Snake flow augmentation. The lower Snake River or John Day dams would not be drawn down. Also, spring and summer Lower Granite flow objectives and June 30 reservoir refill priorities are adjusted from the Base Condition.
- Alternative **A6b** is a continuous study of the system operation under a scenario where the Base Condition is adjusted to incorporate no upper Snake River flow augmentation. The 427 KAF flow augmentation in the Base Condition is eliminated. The lower Snake River or John Day dams would not be drawn down. Again as in Alternative A6a, the spring and summer Lower Granite flow objectives and June 30 reservoir refill priorities are adjusted from the Base Condition.

A feasibility study on drawing down the John Day project is also being conducted. For this study two alternatives are being investigated. They include operating the John Day project at natural river levels or at spillway crest. The John Day operation to natural river level is denoted as series "B" (Table 4-1) and the operation to spillway crest is denoted as series "C".

**Table 4-1.** General Description of Alternatives

| Alternative | Flow Augmentation | | | | Project Drawn Down | | |
|---|---|---|---|---|---|---|---|
| | | | Upper Snake | | Lower | John Day at | JDA at |
| | Columbia | Snake | (khm) | (KAF) | Snake | Natural River | Spillway |
| A1 | Yes | Yes | 52.7 | 427 | No | No | No |
| A2[1/] | Yes | Yes | 52.7 | 427 | No | No | No |
| A3 | Yes | Yes | 52.7 | 427 | Yes | No | No |
| A5 | Yes | No | | | Yes | No | No |
| A6a | Yes | Yes | 176.0 | 1,427 | No | No | No |
| A6b | Yes | Yes | | | No | No | No |
| B1 | Yes | Yes | 52.7 | 427 | Yes | Yes | No |
| B2 | No | No | | | Yes | Yes | No |
| C1 | Yes | Yes | 52.7 | 427 | Yes | No | Yes |
| C2 | No | No | 0 | | Yes | No | Yes |

[1/]A2 has no spill at Lower Granite, Little Goose, Lower Monumental, and McNary.

Below is a brief description of these alternatives followed by the detailed hydroregulation specification. In the "A" series above, John Day was operated according to the Salmon Biological Opinion. The results of this study will not be used to make a decision regarding drawdown at John Day. In these alternatives Libby would still provide higher outflows for sturgeon. Below and in Table 4-1 is a brief description of these alternatives followed by the detailed hydroregulation specification beginning in Section 4.8.

- **Alternative B1:** A continuous study of the system operations under a scenario where the Base Condition is adjusted only for drawdown of all four lower Snake River dams to natural river levels and John Day is operated at natural river level. Flow augmentation on the Columbia and Snake Rivers would remain unchanged.

- **Alternative B2:** The Base Condition is adjusted for drawdown of all four lower Snake River dams to natural river levels and John Day is operated at natural river level. Flow augmentation on the Columbia River and Snake River are removed, thereby freeing up the reservoir operation for power purposes much of the time. Juvenile bypass spill and 1 percent peak operation is retained.

- **Alternative C1:** A continuous study of the system operations under a scenario where the Base Condition is adjusted only for drawdown of all four lower Snake River dams to natural river levels and John Day is operated at spillway crest. Flow augmentation on the Columbia River and Snake River would remain unchanged.

- **Alternative C2:** The system operates under a scenario where the Base Condition is adjusted only for drawdown of all four lower Snake River dams to natural river levels and John Day operated at spillway crest. Flow augmentation on the Columbia River and Snake River would be removed, thereby freeing up the reservoir operations for power purposes much of the time. Juvenile bypass spill and 1 percent peak operation is retained.

### 4.1.2 Hydroregulation Study Steps

The Corps performed one regulation analysis for the base condition and each alternative. The regulation included all the power and non-power requirements described in the following sections.

BPA ran two regulations, an AER Step and an Operational Step. The AER Step is used to determine the project minimum elevations (or maximum draft) using load equal to FELCC and unlimited secondary market. Minimum elevations from the AER Step were input into the Operational Step. The Operational Step used PNCA submitted loads and a limited secondary market. The Operation Step was modeled the same as the AER step, except as specifically addressed below.

### 4.1.3 Stream Flows

#### 4.1.3.1 Modified Stream Flows

The 60 years of modified stream flows used are from *Modified Streamflows 1990 Level of Irrigation*, dated July 1993. They contain the 1928-89 stream flow record adjusted for the 1990 level irrigation withdrawals. Adjustments have been made to these 1990 level modified stream flows due to the BoR's updated Grand Coulee pumping schedule for the Columbia Basin Project. This pumping schedule is included in the BoR February 1, 1996 preliminary PNCA data submittal. BPA used 50 years of stream flow records.

#### 4.1.3.2 Continuous Stream Flow Mode

To measure the impact to power production, a hydroregulation in continuous mode was used to simulate the base condition and alternatives investigated. The study begins on 1 August 1928 and ends on 31 July 1988, a 60-year study. BPA ran through 31 July 1978, a 50-year study.

### 4.1.4 Study Area

#### 4.1.4.1 Regulated Hydroelectric Projects

The Western System Coordinating Council (WSCC) is the largest electrical reliability council in North America encompassing the entire states of Washington, Oregon, Idaho, California, Nevada, Utah, Wyoming, Arizona and parts of Montana, Nebraska, New Mexico, and Texas, as well as British Columbia and Alberta in Canada. In Canada the WSCC includes British Columbia and Alberta. The WSCC is then further subdivided into four general load areas: Northwest Power Pool, Rocky Mountain Power Pool, Arizona-New Mexico Power Pool, and California-Southern Nevada Power Pool.

In 1964 the PNCA was signed by a subgroup of utilities in the NWPP area. This subregion is used as the study area and defines the projects modeled in the hydroregulation. The study area consists of Washington, Oregon, Idaho, and Montana west of the continental divide, and that area within the Columbia Basin in British Columbia and Alberta, Canada.

Hydroelectric projects within the study area that are coordinated with the system load are modeled as regulated hydro projects. Control points were added in locations where flow objectives are placed in the system or where minimum or maximum flows are needed. See Table 4-2 for a complete list of regulated

**Table 4-2.** Regulated Hydroelectric Projects and Control Points

| | | |
|---|---|---|
| White River | Kerr | Priest Rapids |
| Timothy | Thompson Falls | Brownlee |
| Clackamas | Noxon | Oxbow |
| Upper Baker | Cabinet Gorge | Hells Canyon |
| Lower Baker | Priest Lake | Dworshak |
| Ross | Albeni Falls | Lower Granite |
| Diablo | Box Canyon | Little Goose |
| Gorge | Boundary | Lower Monumental |
| Cushman No 1 | Seven Mile | Ice Harbor |
| Cushman No 2 | Waneta | McNary |
| Alder | Upper Falls | John Day |
| La Grande | Monroe Street | Round Butte |
| Libby | Nine Mile | Pelton & Rereg |
| Bonners Ferry | Long Lake | The Dalles |
| Duncan | Little Falls | Bonneville |
| Corra Linn | Grand Coulee | Swift No 1 |
| Kootenay Plants | Chief Joseph | Swift No 2 |
| Canal Plant | Wells | Yale |
| Brilliant | Chelan | Merwin |
| Mica | Rocky Reach | Mossyrock |
| Revelstoke | Rock Island | Mayfield |
| Arrow | Wanapum | Hungry Horse |

hydropower projects and control points used in this study. Oak Grove, North Fork, Faraday, River Mill are modeled as the Clackamas project.

### 4.1.4.2 Independent Hydroelectric Projects

Of the hydroelectric projects found in the Pacific Northwest and the study area there is a subset of plants which are not coordinated within the region. These plants have a fixed generation output and are usually operated on fixed-rule curves or are run-of-river type projects. See Table 4-3 for a list of Indepeondent hydropower projects used to meet the system load of the Pacific Northwest.

## 4.2 The Base Condition or Alternative A1

The Base Condition is a description of how the PNW reservoir system would be operated, assuming the current operating requirements. The base condition was developed during the summer of 1997 and reflects the proposed operations for endangered fish species covered under the Endangered Species Act (ESA) and described in 1) NMFS Biological Opinion of March 2, 1995 titled *Reinitiation of Consultation on the 1994-98 Operation of the Federal Columbia River Power System and Juvenile Transportation Program in 1995 and Future Years* (Salmon Biological Opinion); 2) *USFWS Biological Opinion of March 1, 1995* (Sturgeon Biological Opinion); and 3) the Corps of Engineers Record of Decision (ROD) titled *Columbia River System Operation Review Selection of a System Operation Strategy,* signed February 20, 1997.

**Table 4-3.** Hydropower Independent Projects

| | | |
|---|---|---|
| Jackson | Dexter | Walterville |
| Klamath Lake | Cougar | TW Sullivan |
| John Boyle | Green Peter | Stone Creek |
| Iron Gate | Foster | Bullrun |
| Lost Creek | Detroit | Cowlitz Falls |
| Copco 1&2 | Big Cliff | Meyers Falls |
| Fall Creek | Carmen Smith | Palisades |
| Hills Creek | Trailbridge | Anderson Ranch |
| Lookout Point | Leaburg | Electron |
| Nooksack | Snoqualmie 1&2 | Prospect 14 |
| Eagle Point | Lemolo 1&2 | Clearwater 182 |
| Toketee | Fish Creek | Slide Creek |
| Soda Springs | Condit | Powerdale |
| Naches | Naches Drop | Big Fork |
| Bend | Cline Falls | Wallowa Falls |
| Cedar Falls | Newhalem | Black Canyon |
| Boise R. Diversion | Minidoka | Roza |
| Chandler | Packwood | |

## 4.2.1 System Demand

### 4.2.1.1 Loads

The system demand or load was developed from the Operating Year 1997 Critical Period study run by the NWPP. The NWPP study resulted in a 1-year critical period (September 1, 1936 through April 30, 1937) where the generation during the critical period becomes the firm energy load carrying capability or FELCC. Outside the critical period, in May, June, July, and August, FELCC will come from the PNCA Final Regulation. Only one year of FELCC values are used for all water conditions. Sixty years of FELCC was developed by adding Hydropower Independent generation (see Table 4-4) from 1936-37 to compute system total generation. Then, the system total generation will be reduced by 60 years of hydropower independent generation to produce 60 years of FELCC. These 60 years of loads were used a input to the HYSSR model.

This study reflects coordination between PNCA parties in meeting PNCA FELCC. Therefore, generation from projects owned by non-PNCA parties (Brownlee, Oxbow and Hells Canyon) were not used to meet PNCA FELCC in these studies.

BPA produced 50 years of loads and use the above requirements in their AER Step.

### 4.2.1.2 Secondary Market

This study has a secondary market limit of 9,000 average megawatts (aMW). The transfer capability of secondary generation outside the study area to Northern California is 7,500 MW, to Nevada is 190 MW, to Southern Idaho is 1,200 MW, and to Eastern Montana is 1,200 MW. BPA operated the AER step to an unlimited secondary market.

**Table 4-4.** Hydropower Independent Generation—aMW

| | AUG1 | AUG 2 | SEP | OCT | NOV | DEC | JAN | FEB | MAR | APR1 | APR 2 | MAY | JUN | JUL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 28-29 | 667 | 640 | 667 | 777 | 822 | 678 | 644 | 537 | 667 | 746 | 792 | 1087 | 1078 | 774 |
| 29-30 | 648 | 600 | 585 | 567 | 545 | 853 | 612 | 1016 | 715 | 726 | 714 | 790 | 764 | 699 |
| 30-31 | 605 | 575 | 604 | 608 | 674 | 570 | 632 | 604 | 680 | 903 | 684 | 790 | 698 | 616 |
| 31-32 | 531 | 505 | 557 | 611 | 750 | 638 | 769 | 536 | 1181 | 1085 | 1107 | 1252 | 1137 | 790 |
| 32-33 | 676 | 634 | 645 | 745 | 1027 | 852 | 859 | 543 | 729 | 772 | 860 | 1209 | 1421 | 972 |
| 33-34 | 757 | 706 | 758 | 866 | 905 | 1031 | 1128 | 737 | 755 | 726 | 695 | 711 | 576 | 643 |
| 34-35 | 485 | 479 | 481 | 748 | 1112 | 1025 | 868 | 765 | 693 | 807 | 883 | 1038 | 958 | 690 |
| 35-36 | 600 | 571 | 565 | 648 | 676 | 590 | 1074 | 632 | 785 | 848 | 1019 | 1282 | 1081 | 768 |
| 36-37 | 644 | 612 | 660 | 625 | 568 | 639 | 496 | 533 | 746 | 1001 | 1059 | 1264 | 1322 | 826 |
| 37-38 | 650 | 618 | 647 | 760 | 1101 | 1089 | 1070 | 707 | 903 | 976 | 1294 | 1360 | 1017 | 737 |
| 38-39 | 667 | 653 | 689 | 713 | 919 | 917 | 858 | 694 | 860 | 916 | 931 | 1050 | 890 | 817 |
| 39-40 | 642 | 594 | 618 | 701 | 686 | 831 | 723 | 895 | 1011 | 915 | 828 | 829 | 664 | 668 |
| 40-41 | 599 | 545 | 611 | 672 | 826 | 778 | 772 | 621 | 599 | 589 | 570 | 756 | 670 | 595 |
| 41-42 | 581 | 563 | 666 | 821 | 921 | 1094 | 795 | 705 | 623 | 757 | 764 | 919 | 933 | 743 |
| 42-43 | 648 | 609 | 652 | 646 | 1164 | 1195 | 1094 | 917 | 982 | 1341 | 1301 | 1187 | 1272 | 873 |
| 43-44 | 753 | 739 | 766 | 843 | 940 | 843 | 704 | 676 | 675 | 740 | 759 | 850 | 876 | 767 |
| 44-45 | 642 | 607 | 604 | 641 | 819 | 630 | 875 | 976 | 758 | 849 | 1049 | 1428 | 981 | 716 |
| 45-46 | 615 | 612 | 758 | 760 | 1070 | 1156 | 1110 | 759 | 910 | 954 | 1183 | 1329 | 1201 | 866 |
| 46-47 | 707 | 640 | 697 | 857 | 1135 | 1208 | 901 | 895 | 856 | 1063 | 1027 | 937 | 1012 | 800 |
| 47-48 | 681 | 643 | 694 | 1050 | 1237 | 896 | 1095 | 776 | 782 | 840 | 1043 | 1386 | 1367 | 852 |
| 48-49 | 738 | 696 | 741 | 885 | 1003 | 1024 | 618 | 766 | 1036 | 1119 | 1300 | 1504 | 1112 | 885 |
| 49-50 | 715 | 658 | 698 | 870 | 967 | 836 | 967 | 905 | 1208 | 1243 | 1248 | 1338 | 1373 | 1022 |
| 50-51 | 810 | 806 | 792 | 1093 | 1354 | 1303 | 1239 | 1207 | 1029 | 1224 | 1157 | 1272 | 950 | 831 |
| 51-52 | 740 | 735 | 798 | 1057 | 1137 | 1110 | 873 | 981 | 894 | 1264 | 1304 | 1386 | 1248 | 931 |
| 52-53 | 729 | 716 | 785 | 761 | 757 | 711 | 1254 | 1194 | 879 | 838 | 1005 | 1378 | 1329 | 964 |
| 53-54 | 813 | 788 | 810 | 892 | 1244 | 1273 | 1156 | 1071 | 896 | 1239 | 1164 | 1214 | 1294 | 1002 |
| 54-55 | 846 | 829 | 861 | 922 | 982 | 862 | 791 | 725 | 694 | 838 | 816 | 1229 | 1336 | 1028 |
| 55-56 | 759 | 690 | 739 | 976 | 1271 | 1284 | 1243 | 846 | 982 | 1162 | 1357 | 1466 | 1396 | 988 |
| 56-57 | 796 | 788 | 858 | 1030 | 1145 | 1244 | 824 | 859 | 1212 | 1303 | 1108 | 1259 | 971 | 817 |
| 57-58 | 665 | 655 | 776 | 838 | 944 | 1165 | 1150 | 1168 | 830 | 854 | 1206 | 1259 | 1177 | 850 |
| 58-59 | 731 | 685 | 768 | 844 | 1214 | 1072 | 1200 | 838 | 843 | 976 | 945 | 1135 | 970 | 825 |
| 59-60 | 675 | 642 | 887 | 1016 | 986 | 829 | 687 | 859 | 1001 | 1199 | 1043 | 1354 | 1101 | 763 |
| 60-61 | 674 | 645 | 705 | 798 | 1148 | 954 | 876 | 1216 | 1130 | 946 | 873 | 1170 | 1006 | 713 |
| 61-62 | 620 | 578 | 657 | 823 | 1013 | 1079 | 957 | 763 | 701 | 1159 | 1195 | 1222 | 1011 | 799 |
| 62-63 | 724 | 674 | 701 | 1003 | 1193 | 1138 | 758 | 1034 | 810 | 1034 | 976 | 1247 | 843 | 771 |
| 63-64 | 647 | 594 | 677 | 768 | 1147 | 930 | 1055 | 773 | 768 | 1009 | 983 | 1206 | 1390 | 925 |
| 64-65 | 760 | 742 | 802 | 836 | 974 | 1300 | 1256 | 991 | 952 | 940 | 1078 | 1135 | 1004 | 792 |
| 65-66 | 768 | 747 | 745 | 807 | 964 | 803 | 1012 | 672 | 823 | 1124 | 1016 | 1144 | 923 | 830 |
| 66-67 | 645 | 591 | 647 | 737 | 998 | 1095 | 1108 | 863 | 791 | 866 | 851 | 1126 | 1147 | 798 |
| 67-68 | 648 | 647 | 646 | 926 | 934 | 914 | 997 | 1074 | 881 | 681 | 694 | 874 | 819 | 757 |
| 68-69 | 600 | 610 | 807 | 886 | 1259 | 1102 | 1090 | 743 | 791 | 948 | 1046 | 1442 | 1206 | 757 |
| 69-70 | 662 | 613 | 683 | 854 | 905 | 937 | 1169 | 931 | 844 | 898 | 920 | 1080 | 934 | 766 |
| 70-71 | 641 | 583 | 675 | 810 | 1139 | 1042 | 1260 | 1063 | 1133 | 1195 | 1056 | 1427 | 1354 | 947 |
| 71-72 | 807 | 770 | 880 | 921 | 1205 | 1138 | 1246 | 1225 | 1546 | 1258 | 1174 | 1380 | 1194 | 987 |
| 72-73 | 800 | 785 | 888 | 855 | 951 | 1111 | 1132 | 749 | 714 | 662 | 717 | 886 | 771 | 751 |
| 73-74 | 606 | 568 | 640 | 763 | 1300 | 1267 | 1233 | 949 | 1159 | 1333 | 1181 | 1347 | 1378 | 931 |
| 74-75 | 825 | 779 | 778 | 751 | 897 | 1149 | 1201 | 899 | 1004 | 902 | 950 | 1325 | 1226 | 973 |
| 75-76 | 771 | 758 | 780 | 957 | 1211 | 1286 | 1290 | 932 | 883 | 969 | 1032 | 1229 | 1042 | 926 |
| 76-77 | 831 | 824 | 776 | 762 | 824 | 663 | 602 | 572 | 608 | 617 | 635 | 872 | 711 | 656 |
| 77-78 | 554 | 534 | 572 | 694 | 1200 | 1213 | 990 | 741 | 740 | 759 | 813 | 973 | 806 | 679 |
| 78-79 | 642 | 652 | 793 | 704 | 838 | 906 | 727 | 782 | 984 | 942 | 1038 | 1151 | 805 | 694 |
| 79-80 | 580 | 579 | 653 | 666 | 794 | 941 | 1048 | 771 | 784 | 816 | 979 | 965 | 821 | 691 |
| 80-81 | 573 | 562 | 676 | 621 | 908 | 1120 | 776 | 808 | 717 | 689 | 747 | 833 | 948 | 705 |
| 81-82 | 620 | 569 | 622 | 751 | 917 | 1126 | 966 | 1196 | 1100 | 1031 | 1089 | 1149 | 1077 | 854 |
| 82-83 | 714 | 697 | 811 | 914 | 1042 | 1191 | 1229 | 1021 | 1114 | 1103 | 989 | 1165 | 1096 | 915 |
| 83-84 | 707 | 769 | 825 | 796 | 1154 | 1084 | 1244 | 948 | 1100 | 1138 | 1061 | 1286 | 1268 | 866 |
| 84-85 | 710 | 723 | 864 | 916 | 1252 | 972 | 847 | 682 | 691 | 980 | 1062 | 1155 | 1053 | 766 |
| 85-86 | 649 | 596 | 737 | 862 | 1058 | 815 | 998 | 1138 | 1211 | 972 | 964 | 1070 | 862 | 705 |
| 86-87 | 633 | 611 | 777 | 800 | 1132 | 865 | 887 | 797 | 869 | 759 | 800 | 888 | 724 | 671 |
| 87-88 | 601 | 544 | 576 | 545 | 590 | 832 | 811 | 670 | 753 | 913 | 857 | 1039 | 978 | 675 |
| MAX. | 846 | 829 | 888 | 1093 | 1354 | 1303 | 1290 | 1225 | 1546 | 1341 | 1357 | 1504 | 1421 | 1028 |
| MED. | 666 | 641 | 700 | 804 | 992 | 1024 | 978 | 823 | 850 | 944 | 1010 | 1178 | 1015 | 795 |
| AVE. | 680 | 653 | 714 | 806 | 997 | 987 | 964 | 849 | 884 | 958 | 983 | 1151 | 1043 | 807 |
| MIN. | 485 | 479 | 481 | 545 | 545 | 570 | 496 | 533 | 599 | 589 | 570 | 711 | 576 | 595 |

### 4.2.2 Rule Curves

#### 4.2.2.1 Flood Control Rule Curves

This study used Upper Rule Curves (URC) for flood control, calculated by using observed runoff volume. The upper rule curve file was created for the February 1, 1996 PNCA Data Submittal by the Corps. The data incorporates shifting system flood control from the Dworshak and Brownlee projects, when the April-July runoff volume forecasts are less than 394.7 khm (3.2 MAF) and 715.4 khm (5.8 MAF), respectively, to Grand Coulee. The flood control at Canadian Treaty projects incorporates the 256.6 khm (2.08 MAF) Mica and 629.1 khm (5.1 MAF) Arrow flood control storage allocation. Flood control will take precedence over all non-power requirements, except Libby where the flood control elevations may be exceeded to meet the International Joint Commission (IJC) 1938 Order at Kootenay Lake. BPA used flood control calculated by the Corps using forecasted volume runoff based on Kuehl Moffitt Report dated July 1986.

#### 4.2.2.2 Variable Energy Content and Assured Refill Curves

Variable Energy Content Curves (VECCs) and Assured Refill Curve (ARC) are used to guide the operation in wet water years and are calculated using the Operating Year 1996-97 Power Discharge Requirements (PDRs), distribution factors, and forecast errors which were used in PNCA planning. Canadian Treaty project operations were determined using the 1996-97 Assured Operating Plan (AOP97) PDR and the Arrow Total method. The runoff volume forecast for all projects is based on actual runoff. The VECC at Grand Coulee was limited to elevation 365.8 m (1,220 ft) in all periods due to the Gifford-Inchelium Ferry that cannot operate below this elevation.

BPA used volume forecasts based on the Kuehl Moffitt Report dated July 1986. Although VECC lower limits were eliminated from OY97 refill studies, in the Operational Step, a lower limit of 379.5 m (1,245 ft) in January, 371.9 m (1,220 ft) February through April, 378.0 m (1,240 ft) in May, and 391.7 m (1,285 ft) in June at Coulee was used in calculating the VECC during period in which the system is generating surplus energy. The VECCs for the Federal projects were based on the Kuehl Moffitt volume forecasts. The Canadian VECC were based on historical volumes.

#### 4.2.2.3 Critical Rule Curves

CRCs are used to guide the operations in critical water years in accordance with PNCA and were developed during PNCA planning and published in the Final Regulation. The first year critical rule curve, CRC1, used in this study is the CRC1 from the Operating Year 1996-97 Final Regulation. The CRC2 used in this study is the CRC3 from Operating year 1994-95 and the CRC3 used in this study is the CRC4 from the Operating Year 1993-94. There is no CRC4 due to the one-year critical period so CRC4 was set to empty. Reservoirs will draft proportionally between these rule curves when the system load is not met.

### 4.2.3 Project Operations

#### 4.2.3.1 Reservoir Storage Initialization

Storage reservoirs were initialized to full on 1 August 1928, with the following exceptions. Mica usually fills in August so it was initialized to the July Mica target content of 87.1 khm (356.2 ksfd). Libby, Hungry Horse, Grand Coulee, and Dworshak are expected to augment for downstream flow objectives at McNary and Lower Granite down to their draft limits in July so they were initialized to

elevation 746.5 m (2,449 ft) [558.0 khm (2,281.3 ksfd)], 1,082.0 m (3,550 ft) [349.2 khm (1,427.7 ksfd), 391.7 m (1,285.0 ft) [591.2 khm (2,417.1 ksfd)] and 463.3 m (1,520.0 ft) [96.9 khm (396.0 ksfd)], respectively. John Day is operated within .5 m (1.5 ft) of elevation 80.0 m (262.5 ft) through July so it was initialized to elevation 80.0 m (262.5 ft) [31.2 khm (127.7 ksfd)]. In the IJC 1938 Order, there were maximum lake levels at Corra Linn set for July, so it was initialized to elevation 531.4 m (1,743.32 ft) [55.5 khm (226.7 ksfd)]. Brownlee was initialized to elevation 630.6 m (2,069.0 ft) [106.7 khm (436.3 ksfd)] in July.

#### 4.2.3.2 Non-Power Requirements

All projects followed the non-power requirements from the PNCA plant data book, updated September 30, 1996, or which were submitted for the Operating Year 1997 PNCA planning process on February 1, 1996, except as noted within.

#### 4.2.3.3 Canadian Treaty Storage Operation

The Columbia River Treaty prescribes the method for determining the Canadian storage operation and the Canadian entitlement for such operation. This storage operation is determined 6 years advance in assured operating plans (AOPS) and modified to achieve mutual benefit in detailed operating plans. The Canadian Treaty storage projects, Mica, Duncan, and Arrow were operated to the AOP 1996-97 operations including changes agreed to by the Entities as described in the 1996-97 Detailed Operating Plan (DOP97). The Canadian Treaty projects were fixed to the operation resulting from the 60-year DOP97 Treaty Storage Regulation. This 60-year operation was prepared by the Corps for use in the 1996-97 PNCA studies. The regulation incorporates the Arrow Total method of computing VECC. BPA used a 50-year DOP Treaty Storage Regulation that was adopted for PNCA. Mica data logic in the HYDROSIM program was turned off. Mica's minimum storage content was reset to 0.0 khm (0.0 ksfd) so that drafting below 622.2 khm (2,543.8 ksfd)(normal minimum content) can occur.

#### 4.2.3.4 Libby Project Operation

The Libby project operation was consistent with the Sturgeon and Salmon Biological Opinion. During September through December, Libby was operated to meet FELCC down to the December 31 flood control elevation of 734.9 m (2,411.0 ft) [367.4 khm (1,502.2 ksfd)]. In January through mid-April, Libby was operated on minimum flow or flood control objectives as defined in the Salmon Biological Opinion. It should be noted that Libby can exceed URC in some periods when discharges would have forced Corra Linn Reservoir above allowable lake levels as defined in the IJC 1938 Order.

From mid-April through July Libby was operated for protection of sturgeon in all but 20 percent of the lowest observed April-September runoff volumes at Libby by supporting Bonners Ferry minimum flows. Sturgeon releases were not provided in operating years 1928-29, 1930-31, 1935-36, 1936-37, 1939-40, 1940-41, 1943-44, 1944-45, 1969-70, 1977-78, 1978-79, and 1987-88. During these years salmon releases were provided as described below. BPA used the May 1 volume forecast based on Kuehl Moffitt Report to determine the years when sturgeon releases would not be provided. Refer to the Flow Objective Table 4-9 in the OPER Step to identify the years when these flows were not provided. Sturgeon flow objectives from April 16th through April 30 were to increase flows at Libby so that Bonners Ferry flow was at 424.8 $m^3/s$ (15,000 cfs) on May 1. From May 1 through 19, a minimum flow at Bonners Ferry of 424.8 $m^3/s$ (15,000 cfs) was maintained.

From May 20 through June 30 sturgeon augmentation from Libby attempted to maintain a maximum flow at Bonners Ferry of 991.0 $m^3/s$ (35,000 cfs). From July 1 through July 21 a minimum flow at Bonners Ferry of 311.5 $m^3/s$ (11,000 cfs) was maintained. During July 22 through July 31 a minimum flow at Libby of 113.3 $m^3/s$ (4,000 cfs) was maintained after ramping down from 311.5 $m^3/s$ (11,000 cfs). Libby's maximum outflow from mid-April through August was equal to powerhouse hydraulic capacity without spilling.

In July, mid-August and August, Libby was operated to as low as elevation 746.5 m (2,449 ft); 743.4 m (2,439 ft); and 743.4 m (2,439 ft) [558.0 khm (2,281.3 ksfd); 504.2 khm (2,061.3 ksfd); and 504.2 khm (2,061.3 ksfd)] to contribute to flow augmentation at McNary. During years when sturgeon releases were not provided Libby supported McNary flow objective April 16 through August. During these years Libby was operated on minimum flow or flood control January through mid-April. Libby supported McNary flow objective in the last part of April, May, June, July, the first and last part of August down to elevation 737.6 m (2,420 ft); 737.6 m (2,420 ft); 743.4 m (2,439 ft); 746.5 m (2,449 ft); 743.4 m (2,439 ft); and 743.4 m (2,439 ft), respectively.

### 4.2.3.5 Hungry Horse Project Operation

Hungry Horse was operated to meet FELCC September through December subject to draft limits of elevation 1,076.2 m (3,531 ft); 1,074.7 m (3,526 ft); 1,073.2 m (3,521 ft); and 1,071.4 m (3,515.0 feet) [297.4 khm (1,215.7 ksfd); 284.2 khm (1,162.0 ksfd); 271.1 khm (1,108.3 ksfd); and 256.6 khm (1,049.0 ksfd)], respectively. From January through mid-April, Hungry Horse was free to operate to meet FELCC above its Biological Rule Curves objectives as defined in the Salmon Biological Opinion (Calculated according to instructions in the 1996-97 PNCA Operating Procedures). See Table 4-5. On April 30, May 31, June 30, July 31, August 15 and August 31, Hungry Horse may draft to limits of elevation 1,079.0 m (3,540 ft); 1,079.0 m (3,540 ft); 1,079.0 m (3,540 ft); 1,082.0 m (3,550 ft); 1,079.0 m (3,540 ft); and 1,079.0 m (3,540.0 ft) [(321.0 khm) 1,312.3 ksfd; (321.0 khm) 1,312.3 ksfd; (321.0 khm) 1,312.3 ksfd; (349.2 khm) 1,427.7 ksfd; (321.0 khm)1,312.3 ksfd; and (321.0 khm) 1,312.3 ksfd] by supporting McNary flow objectives. Hungry Horse was operated to support a Columbia Falls minimum flow of 99.1 $m^3/s$ (3,500 cfs) year round and maximum flow of 127.4 $m^3/s$ (4,500 cfs) October 15 through December 15. The reservoir storage-elevation relationship reflected 3 percent bank storage. Hungry Horse maximum outflow from mid-April through August is powerhouse hydraulic capacity plus 85 $m^3/s$ (3,000 cfs) spill.

### 4.2.3.6 Albeni Falls Project Operation

Albeni Falls was operated in September to elevation 627.9 m (2,060.0 ft) [113.9 khm (465.7 ksfd)]. In October through April, Albeni Falls was operated to elevation 626.4 m (2,055.0 ft) [57.4 khm (234.7 ksfd)]. In May, Albeni Falls was operated to elevation 627.0 m (2,057.0 ft) [79.9 khm (325.7 ksfd)]. In June through August, Albeni Falls is operated to full, elevation 628.7 m (2,062.5 ft) [142.5 khm (582.4 ksfd)].

### 4.2.3.7 Grand Coulee Project Operation

Grand Coulee was operated to meet FELCC September through December subject to draft limits of elevation 390.1 m (1,280 ft); 390.1 m (1,280 ft); 388.6 m (1,275 ft); and 385.6 m (1,265 ft), respectively. BPA did not model these draft limits in the AER Step. In January through mid-April,

**Table 4-5.** 1996-97 PNCA Biological Rule Curves for Hungry Horse and Grand Coulee—ft

| Year 19__ | JAN | FEB | MAR | AP1 | Year 19__ | JAN | FEB | MAR | AP1 |
|---|---|---|---|---|---|---|---|---|---|
| 29 | 3528.8 | 3523.8 | 3519.6 | 3520.0 | 29 | 1271.3 | 1277.8 | 1272.4 | 1280.2 |
| 30 | 3540.5 | 3535.6 | 3531.0 | 3533.7 | 30 | 1290.0 | 1288.7 | 1282.2 | 1281.5 |
| 31 | 3537.7 | 3533.3 | 3529.3 | 3531.7 | 31 | 1290.0 | 1290.0 | 1282.9 | 1281.5 |
| 32 | 3496.2 | 3492.2 | 3496.0 | 3501.2 | 32 | 1208.0 | 1208.0 | 1211.4 | 1220.0 |
| 33 | 3462.5 | 3456.5 | 3452.3 | 3458.6 | 33 | 1208.0 | 1208.0 | 1209.3 | 1220.3 |
| 34 | 3508.2 | 3510.2 | 3513.8 | 3518.7 | 34 | 1208.0 | 1210.4 | 1234.9 | 1246.2 |
| 35 | 3512.4 | 3511.1 | 3507.9 | 3509.2 | 35 | 1208.0 | 1208.0 | 1232.6 | 1252.4 |
| 36 | 3522.2 | 3516.3 | 3511.8 | 3514.0 | 36 | 1211.6 | 1216.3 | 1234.1 | 1243.1 |
| 37 | 3536.4 | 3529.9 | 3523.7 | 3523.4 | 37 | 1290.0 | 1288.7 | 1282.2 | 1280.2 |
| 38 | 3521.8 | 3517.4 | 3514.1 | 3517.5 | 38 | 1208.0 | 1208.0 | 1230.5 | 1225.9 |
| 39 | 3516.5 | 3510.8 | 3509.0 | 3513.2 | 39 | 1265.2 | 1267.9 | 1274.4 | 1268.1 |
| 40 | 3542.0 | 3536.6 | 3533.1 | 3535.6 | 40 | 1290.0 | 1286.2 | 1279.2 | 1273.7 |
| 41 | 3560.0 | 3560.0 | 3555.9 | 3557.2 | 41 | 1289.3 | 1285.9 | 1280.0 | 1281.9 |
| 42 | 3528.7 | 3525.2 | 3520.7 | 3523.6 | 42 | 1208.0 | 1229.8 | 1251.3 | 1252.8 |
| 43 | 3478.4 | 3475.9 | 3474.1 | 3481.0 | 43 | 1208.0 | 1208.0 | 1239.1 | 1232.9 |
| 44 | 3555.3 | 3549.3 | 3543.4 | 3543.8 | 44 | 1289.7 | 1280.8 | 1280.8 | 1282.2 |
| 45 | 3523.8 | 3518.9 | 3513.9 | 3514.4 | 45 | 1249.7 | 1246.8 | 1252.3 | 1260.2 |
| 46 | 3507.3 | 3503.3 | 3501.9 | 3506.4 | 46 | 1208.0 | 1208.0 | 1208.0 | 1218.8 |
| 47 | 3485.9 | 3483.2 | 3483.7 | 3489.6 | 47 | 1208.0 | 1208.0 | 1227.7 | 1226.3 |
| 48 | 3486.4 | 3481.5 | 3477.4 | 3479.6 | 48 | 1208.0 | 1208.0 | 1208.0 | 1208.0 |
| 49 | 3521.5 | 3516.1 | 3511.2 | 3514.8 | 49 | 1208.0 | 1208.2 | 1231.2 | 1233.5 |
| 50 | 3449.0 | 3444.9 | 3444.6 | 3451.3 | 50 | 1208.0 | 1208.0 | 1208.0 | 1213.0 |
| 51 | 3482.2 | 3484.9 | 3484.8 | 3490.2 | 51 | 1208.0 | 1208.0 | 1223.4 | 1221.5 |
| 52 | 3519.8 | 3515.6 | 3511.6 | 3515.5 | 52 | 1208.0 | 1208.0 | 1230.4 | 1225.7 |
| 53 | 3496.8 | 3495.0 | 3491.7 | 3494.6 | 53 | 1208.0 | 1208.0 | 1208.0 | 1221.0 |
| 54 | 3461.4 | 3456.1 | 3452.8 | 3457.5 | 54 | 1208.0 | 1208.0 | 1208.0 | 1208.0 |
| 55 | 3507.0 | 3502.7 | 3498.1 | 3499.8 | 55 | 1208.0 | 1208.0 | 1208.0 | 1211.9 |
| 56 | 3486.7 | 3482.4 | 3479.2 | 3484.1 | 56 | 1208.0 | 1208.0 | 1208.0 | 1208.0 |
| 57 | 3514.3 | 3509.7 | 3506.3 | 3508.3 | 57 | 1208.0 | 1208.0 | 1215.9 | 1221.5 |
| 58 | 3515.4 | 3510.2 | 3506.6 | 3510.1 | 58 | 1208.0 | 1208.0 | 1220.4 | 1222.8 |
| 59 | 3439.6 | 3438.0 | 3436.9 | 3446.6 | 59 | 1208.0 | 1208.0 | 1208.0 | 1212.1 |
| 60 | 3504.6 | 3501.8 | 3503.7 | 3508.1 | 60 | 1208.0 | 1208.0 | 1229.3 | 1231.3 |
| 61 | 3495.5 | 3492.9 | 3492.3 | 3497.6 | 61 | 1208.0 | 1208.0 | 1208.0 | 1217.1 |
| 62 | 3501.7 | 3498.3 | 3494.2 | 3499.6 | 62 | 1208.0 | 1208.0 | 1234.7 | 1231.9 |
| 63 | 3521.9 | 3521.9 | 3520.4 | 3523.3 | 63 | 1215.1 | 1238.8 | 1256.8 | 1255.5 |
| 64 | 3479.7 | 3473.3 | 3467.2 | 3470.5 | 64 | 1208.0 | 1208.0 | 1213.5 | 1217.8 |
| 65 | 3471.0 | 3468.2 | 3464.4 | 3471.0 | 65 | 1208.0 | 1208.0 | 1232.0 | 1227.8 |
| 66 | 3516.0 | 3511.4 | 3507.9 | 3511.8 | 66 | 1208.0 | 1238.4 | 1258.8 | 1257.0 |
| 67 | 3471.3 | 3469.2 | 3466.1 | 3470.8 | 67 | 1208.0 | 1208.0 | 1208.0 | 1210.7 |
| 68 | 3500.2 | 3496.9 | 3498.8 | 3502.5 | 68 | 1208.0 | 1227.2 | 1248.8 | 1248.9 |
| 69 | 3515.9 | 3512.3 | 3508.6 | 3512.7 | 69 | 1208.0 | 1208.0 | 1212.1 | 1221.9 |
| 70 | 3499.1 | 3493.5 | 3488.3 | 3490.2 | 70 | 1215.5 | 1219.9 | 1237.6 | 1237.1 |
| 71 | 3456.1 | 3460.5 | 3460.3 | 3466.7 | 71 | 1208.0 | 1208.0 | 1208.0 | 1209.5 |
| 72 | 3451.2 | 3444.9 | 3451.1 | 3460.2 | 72 | 1208.0 | 1208.0 | 1208.0 | 1208.0 |
| 73 | 3536.0 | 3531.8 | 3527.0 | 3528.3 | 73 | 1272.9 | 1282.1 | 1275.0 | 1281.5 |
| 74 | 3437.6 | 3440.2 | 3441.7 | 3451.0 | 74 | 1208.0 | 1208.0 | 1208.0 | 1208.0 |
| 75 | 3482.3 | 3476.6 | 3471.0 | 3472.3 | 75 | 1208.0 | 1208.0 | 1221.9 | 1226.8 |
| 76 | 3488.9 | 3485.6 | 3482.0 | 3487.5 | 76 | 1208.0 | 1208.0 | 1216.4 | 1223.9 |
| 77 | 3558.7 | 3553.6 | 3548.1 | 3548.6 | 77 | 1285.2 | 1279.7 | 1280.4 | 1282.5 |
| 78 | 3498.0 | 3492.6 | 3490.7 | 3496.2 | 78 | 1208.0 | 1208.0 | 1228.0 | 1225.4 |
| 79 | 3510.9 | 3505.8 | 3503.4 | 3506.3 | 79 | 1279.4 | 1284.6 | 1267.5 | 1268.6 |
| 80 | 3527.9 | 3522.4 | 3517.5 | 3517.7 | 80 | 1208.0 | 1211.9 | 1236.0 | 1246.8 |
| 81 | 3496.0 | 3495.7 | 3497.0 | 3501.8 | 81 | 1208.0 | 1208.0 | 1231.4 | 1231.9 |
| 82 | 3473.5 | 3471.6 | 3471.6 | 3475.9 | 82 | 1208.0 | 1208.0 | 1208.3 | 1218.1 |
| 83 | 3516.9 | 3513.2 | 3512.6 | 3515.3 | 83 | 1208.0 | 1208.0 | 1226.2 | 1228.8 |
| 84 | 3519.4 | 3517.4 | 3515.3 | 3517.8 | 84 | 1208.0 | 1208.0 | 1218.8 | 1223.0 |
| 85 | 3509.3 | 3504.6 | 3500.4 | 3504.2 | 85 | 1230.0 | 1238.3 | 1251.0 | 1250.6 |
| 86 | 3519.5 | 3517.3 | 3520.1 | 3523.8 | 86 | 1208.0 | 1229.4 | 1248.7 | 1244.3 |
| 87 | 3548.0 | 3543.2 | 3542.5 | 3544.8 | 87 | 1289.8 | 1288.1 | 1281.7 | 1280.5 |
| 88 | 3544.9 | 3539.0 | 3534.1 | 3536.5 | 88 | 1290.0 | 1290.0 | 1283.1 | 1280.4 |

minimum storage values were calculated for Grand Coulee (Biological Rule Curves) which guide the reservoir to its expected April 15 URC elevation. See Table 4-5. Grand Coulee was then operated to meet FELCC above these minimum storage points. Storage releases needed for the appropriate Vernita Bar minimum flow requirement was also provided December through May. From mid-April through May, Grand Coulee was drafted to the lower of flood control or elevation 381 m (1,250 ft) to support McNary flow augmentation objectives. In June, Grand Coulee was drafted to the lower of flood control or elevation 390.1 m (1,280 ft) to support McNary flow augmentation objectives. July, mid-August and August, Grand Coulee was drafted as low as elevation 391.7 m (1,285 ft); 390.1 m (1,280.0 ft); and 390.1 m (1,280.0 ft) [591.2 khm (2,417.1 ksfd); 542.1 khm (2,216.4 ksfd); and 542.1 khm (2,216.4 ksfd)] to support McNary flow augmentation objectives. At-site the project minimum flow was equal to 849.5 $m^3/s$ (30,000 cfs). Grand Coulee is subject to a drawdown limit of 0.5 m (1.5 ft) per day for side slope stability, but it was modeled as 0.4 m (1.3 ft) per day over an entire month.

### 4.2.3.8 Brownlee Project Operation

Brownlee was operated on flood control from February through April. In May the reservoir was operated to elevation 630.6 m (2,069 ft) or lower if required for flood control. In June, Brownlee was filled if necessary and maintained at elevation 633.1 m (2,077 ft). In July, the first and last part of August, the reservoir was drafted to elevation 630.6 m (2,069 ft); 624.8 m (2,050 ft); and 624.2 m (2,048 ft), respectively, for flow augmentation which includes both Idaho Power Company contribution and shaping of upper Snake water by the end of August. In September and October, the reservoir operated to elevation 624.8 m (2,050 ft) and 624.2 m (2,048 ft), respectively in anticipation of providing a maximum discharge of 254.8 $m^3/s$ (9,000 cfs) from mid-October through November. Outflows up to 566.3 $m^3/s$ (20,000 cfs) were allowed in October (the average of 849.5 $m^3/s$ (30,000 cfs) in the first half and 254.8 $m^3/s$ (9,000 cfs) in the second half of the month). Discharges higher than 254.8 $m^3/s$ (9,000 cfs) were not allowed in November. By the end of December and January, the reservoir is operated at elevation 630.9 m (2,070 ft) and 627.9 m (2,060 ft), respectively.

### 4.2.3.9 Dworshak Project Operation

Dworshak operation was set on minimum flow of 36.8 $m^3/s$ (1,300 cfs) all periods or flood control objectives as defined in the Salmon Biological Opinion, with the exception of the last part of April through August when it operates to meet Lower Granite flow augmentation objectives. Dworshak was drafted to elevation 463.3 m (1,520 ft) by August 31 to support Lower Granite flow augmentation objectives. Dworshak's outflow was limited to 396.4 $m^3/s$ (14,000 cfs) during the flow augmentation period (mid-April through August) and was limited to 707.9 $m^3/s$ (25,000 cfs) in all other periods for downstream flood control. This operation is described in the February 1, 1996 PNCA data submittal.

### 4.2.3.10 John Day Project Operation

John Day was operated at elevation 80.0 m (262.5 ft) from mid-April through September as identified in the Salmon Biological Opinion. From October through mid-April, John Day operated to elevation 80.8 m (265 ft) [46.7 khm (191.0 ksfd)].

#### 4.2.3.11 Corra Linn Project Operation

Kootenay Lake was operated as necessary, up to free flow, to maintain the lake level below the level specified by the IJC 1938 Order and the calculated "allowable elevation" at Queens Bay. This was implemented using the 5-step method as developed by the Columbia River Treaty Operating Committee. After August 31, the lake level was raised to elevation 532 m (1,745.3 ft) at the Queens Bay gage. This maximum elevation at Queens Bay was in effect through January 7. After January 7 the lake was lowered to elevation 531.6 m (1,744 ft) on February 1, elevation 531.1 m (1,742.4 ft) on March 1, and elevation 530.1 m (1,739.3 ft) on April 1. From April through August 31, if the lake exceeded elevation 530.1 m (1,739.3 ft) at the Queens Bay gage, then it was operated using the "allowable elevation" calculation to determine the Queens Bay maximum allowable elevation until the elevation at the Nelson gage drafted back to elevation 531.4 m (1,743.3 ft).

### 4.2.4 System Operations

#### 4.2.4.1 McNary Flow Augmentation Objectives

During April 20 through June a sliding scale of flow augmentation objectives of 6,229.7 $m^3/s$ (220,000 cfs) to 7,362.4 $m^3/s$ (260,000 cfs) was used at McNary. It was based on The Dalles April 1, January through July volume runoff. A straight-line interpolation was used for flow objectives, for volume forecasts between 10,484.6 khm (85 MAF) and 12,951.6 khm (105.0 MAF). Maximum and minimum objectives are 7,362.4 $m^3/s$ (260,000 cfs) and 6,229.7 $m^3/s$ (220,000 cfs), when the volume forecast was greater than 12,951.6 khm (105.0 MAF) and less than 10,484.6 khm (85 MAF), respectively. The second half of April values were prorated with 4 days at 4,389.1 $m^3/s$ (155,000 cfs) and 11 days at from 6,229.7 $m^3/s$ (220,000 cfs) to 7,362.4 $m^3/s$ (260,000 cfs). July and August flow objectives were 5,663.4 $m^3/s$ (200,000 cfs). The priority for releasing water from upstream reservoirs for flow augmentation was Grand Coulee, Libby and Hungry Horse. The first priority was to support flow objectives and secondly to fill by June 30. These objectives are from the Salmon Biological Opinion.

Grand Coulee, Libby, and Hungry Horse operated in an attempt to meet these flow objectives down to the reservoir elevations or draft limits identified in the Al Wright E90 study. These draft limits were set at reservoirs to proportion augmentation between spring and summer season. Actual elevations of the draft limits are identified in the project operation paragraph for each reservoir.

#### 4.2.4.2 Lower Granite Flow Augmentation Objectives

At Lower Granite a sliding scale was used to determine flow augmentation objectives. When the April 1, April through July runoff forecast at Lower Granite was less than 1,973.6 khm (16 MAF), then the mid-April through June 20 flow objective was 2,406.9 $m^3/s$ (85,000 cfs) and the June 21 through August flow objective was 1,415.8 $m^3/s$ (50,000 cfs). When the April 1, April through July forecast at Lower Granite was greater than 2,467.0 khm (20 MAF), then the mid-April through June 20 flow objective was 2,831.7 $m^3/s$ (100,000 cfs). When the April 1, April through July forecast at Lower Granite was greater than 3,453.8 khm (28 MAF), then the June 21 through August flow objective was 1,557.4 $m^3/s$ (55,000 cfs). The spring flow objectives were interpolated from forecasts between 1,973.6 khm (16 MAF) and 2,467.0 khm (20 MAF) and the spring flow objectives were interpolated for forecasts between 1,973.6 khm (16 MAF) and 3,453.8 khm (28 MAF). The first priority was to support flow objectives and secondly to fill by June 30. Dworshak utilized the

draft limits from the Al Wright E90 study discussed above. These objectives are from the Salmon Biological Opinion.

### 4.2.4.3 Vernita Bar Flow Augmentation Objective

The Vernita Bar minimum flow for December through May varied by water condition, with minimum flows established as the lesser of 68 percent of Wanapum's October or November flows, or 1,982.2 $m^3/s$ (70,000 cfs). Values less than 1,982.2 $m^3/s$ (70,000 cfs) are rounded to the nearest 1,41.6 $m^3/s$ (5,000 cfs). The minimum protection level flow at Vernita Bar will be 1,415.8 $m^3/s$ (50,000 cfs). These requirements are from the Vernita Bar Agreement and are in the 1997 PNCA Data Submittal.

### 4.2.4.4 Upper Snake Flow Augmentation

This operation tries to release 52.7 khm (427 KAF) from the upper Snake River in as many years as possible over the 60-year record during the May through August period. The adjustments to Brownlee inflows from the Upper Snake reservoir operations came from the BoR in May 1997. This requirement is identified in the Salmon Biological Opinion. See Table 4-6. BPA used 50 years of these data.

### 4.2.4.5 Operation Within 1 Percent Peak Efficiency

The Lower Snake River Hydropower Project (Lower Granite, Little Goose, Lower Monumental, and Ice Harbor) and the four lower Columbia River projects (McNary, John Day, The Dalles, and Bonneville) each were required to operate their turbines within 1 percent of peak efficiency during the period of March through November. This requirement is identified in the Salmon Biological Opinion. BPA modeled this requirement as reflected in a hydro availability file that limits the maximum generation capability of each project in each of the fourteen periods. No other hydropower outages were assumed.

### 4.2.4.6 Lower Snake Operation at Minimum Pool

The four lower Snake hydropower facilities were operated at Minimum Operating Pool (MOP) in accordance with the 1997 PNCA Data Submittal and the Salmon Biological Opinion. As identified in the Salmon Biological Opinion, Little Goose, Lower Monumental, and Ice Harbor were operated within one foot of MOP during the period from approximately April 10 through August 31. Lower Granite was operated within one foot of MOP from approximately April 10 through November 15. The MOP for Lower Granite, Little Goose, Lower Monumental, and Ice Harbor were elevations 223.4 m (733 ft), 192.9 m (633 ft), 163.7 m (537.7 ft), and 133.2 m (437 ft), respectively. During the rest of the year Lower Granite, Little Goose, Lower Monumental, and Ice Harbor were operated at elevations 224.9 m (738 ft), 194.5 m (638 ft), 164.6 m (540 ft), and 134.1 m (440 ft), respectively.

### 4.2.4.7 Juvenile Bypass Fish Spill at Federal Projects

Generation at the Lower Snake River Project and the four lower Columbia River projects (Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, John Day, The Dalles, and Bonneville) was reduced further with the inclusion of Juvenile Bypass Fish Spill as reflected in the Salmon Biological Opinion. When the regulated outflow at Lower Granite was less than 2,831.7 $m^3/s$ (100,000 cfs), then there was no spill at the project; otherwise, spill was 80 percent of regulated flow at Lower Granite. If the regulated outflow at Lower Granite was less than

**Table 4-6.** Upper Snake 427 KAF Flow Augmentation—cfs

| YEAR | AUG | SEP | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1928-29 | (2289) | (693) | 458 | 0 | 3624 | 0 | 0 | 0 | 0 | 0 | (757) | (2440) |
| 1929-30 | (1810) | (1204) | 223 | 1317 | 0 | 2559 | 364 | 0 | 0 | 0 | (496) | (2089) |
| 1930-31 | (1764) | (1063) | 270 | 0 | 1171 | 0 | 904 | 470 | 0 | 0 | (732) | (2309) |
| 1931-32 | (2395) | (1220) | 160 | 210 | 550 | 0 | 100 | 0 | 0 | 1446 | 1368 | (2440) |
| 1932-33 | (1869) | 623 | 878 | 107 | 148 | 0 | 169 | 256 | 264 | 697 | 1732 | (2439) |
| 1933-34 | (1848) | 423 | 960 | 135 | 100 | 200 | 432 | 0 | 0 | 42 | (460) | (2029) |
| 1934-35 | (306) | (536) | 484 | 78 | 42 | 33 | 8 | (3) | 0 | 0 | (248) | (2439) |
| 1935-36 | (1628) | (249) | 324 | 78 | 234 | 202 | 11 | (8) | 1466 | 1831 | (534) | (2440) |
| 1936-37 | (2440) | (802) | 56 | 164 | 48 | 0 | 541 | 616 | 331 | 0 | (697) | (2213) |
| 1937-38 | (1274) | (412) | 797 | 200 | 182 | 200 | 1194 | 2329 | 3693 | 3232 | (521) | (2440) |
| 1938-39 | (2099) | (1030) | 1724 | 380 | 1275 | 2213 | 0 | 0 | 1078 | 0 | (756) | (2413) |
| 1939-40 | (2175) | (1228) | 120 | 11 | 0 | 0 | 7 | 386 | 2440 | 936 | (699) | (2440) |
| 1940-41 | (2339) | (522) | 1095 | 594 | 759 | 0 | 571 | 298 | 368 | 391 | 217 | (2080) |
| 1941-42 | (2440) | (933) | 1447 | 857 | 940 | 0 | 93 | 477 | 1805 | 950 | (642) | (2440) |
| 1942-43 | (2440) | (659) | 641 | 0 | 693 | 360 | 866 | 5879 | 5 | 26 | 633 | (2439) |
| 1943-44 | (2416) | (1378) | 560 | 648 | 855 | 0 | 200 | 738 | 1 | 0 | (621) | (2356) |
| 1944-45 | (2000) | (1304) | 305 | 487 | 1370 | 2916 | 1357 | 0 | 1261 | 258 | 550 | (2440) |
| 1945-46 | (2410) | (46) | 650 | 737 | 2696 | 91 | 603 | 130 | 892 | 0 | (757) | (2440) |
| 1946-47 | (2100) | (1078) | 639 | 1 | 4374 | 558 | 640 | 68 | 0 | 0 | (757) | (2440) |
| 1947-48 | (2100) | (987) | 1512 | 0 | 3038 | 0 | 0 | 169 | 818 | 621 | (756) | (2440) |
| 1948-49 | (2100) | (963) | 1654 | 96 | 122 | 2469 | 0 | 816 | 743 | 0 | (604) | (2440) |
| 1949-50 | (2100) | (578) | 1348 | 384 | 0 | 2217 | 0 | 568 | 958 | 0 | 0 | (2439) |
| 1950-51 | (2439) | (1078) | 2127 | 2808 | 545 | 171 | 336 | 0 | 0 | 0 | (756) | (2440) |
| 1951-52 | (2434) | (826) | 500 | 1932 | 515 | 3075 | 12 | 0 | 0 | 0 | (756) | (2440) |
| 1952-53 | (2440) | (1054) | 1667 | 150 | 2788 | 410 | 715 | 0 | 853 | 0 | 0 | (2439) |
| 1953-54 | (2099) | (1078) | 785 | 2161 | 0 | 1013 | 715 | 306 | 688 | 0 | (756) | (2439) |
| 1954-55 | (2440) | (839) | 538 | 2910 | 0 | 1478 | 100 | 0 | 0 | 292 | (191) | (2240) |
| 1955-56 | (2339) | (656) | 665 | 570 | 1291 | 3740 | 0 | 163 | 0 | 13 | (756) | (2440) |
| 1956-57 | (2439) | 154 | 522 | 911 | 2430 | 0 | 738 | 116 | 798 | 0 | (251) | (2440) |
| 1957-58 | (2289) | (609) | 544 | 33 | 3794 | 0 | 481 | 120 | 600 | 0 | (756) | (2440) |
| 1958-59 | (2290) | (733) | 707 | 313 | 0 | 2846 | 983 | 561 | 805 | 0 | (757) | (2440) |
| 1959-60 | (2321) | (1079) | 150 | 197 | 298 | 2137 | 1068 | 657 | 1 | 902 | (756) | (2439) |
| 1960-61 | (2019) | 313 | 362 | 64 | 392 | 0 | 882 | 195 | 0 | 321 | (130) | (2440) |
| 1961-62 | (2439) | (1043) | 1022 | 845 | 99 | 0 | 1874 | 1085 | 3563 | 992 | (756) | (2440) |
| 1962-63 | (1949) | (578) | 1104 | 2175 | 899 | 691 | 26 | 0 | 671 | (1 | (757) | (2440) |
| 1963-64 | (2290) | (754) | 465 | 990 | 1116 | 2072 | 694 | 236 | 91 | 406 | 0 | (2440) |
| 1964-65 | (2440) | (1013) | 1705 | 0 | 3518 | 400 | 0 | 185 | 50 | 0 | 0 | (2439) |
| 1965-66 | (1839) | 578 | 1628 | 989 | 264 | 0 | 0 | 0 | 0 | 430 | (342) | (2440) |
| 1966-67 | (2439) | (1304) | 147 | 16 | 0 | 0 | 133 | 786 | 4058 | 1840 | 0 | (2440) |
| 1967-68 | (2440) | 105 | 616 | 0 | 2495 | 252 | 0 | 0 | 55 | 407 | 259 | (2439) |
| 1968-69 | (2339) | (608) | 536 | 0 | 1369 | 1917 | 1659 | 348 | 107 | 114 | (756) | (2440) |
| 1969-70 | (2146) | (578) | 1534 | 109 | 932 | 2038 | 507 | 1 | 694 | 0 | (242) | (2440) |
| 1970-71 | (2440) | (1078) | 850 | 329 | 2085 | 2844 | 0 | 0 | 0 | 0 | (757) | (1714) |
| 1971-72 | (987) | 125 | 1434 | 489 | 174 | 254 | 516 | 460 | 0 | 0 | 0 | (2439) |
| 1972-73 | (2440) | (1078) | 3713 | 617 | 240 | 0 | 448 | 0 | 0 | 0 | (700) | (2439) |
| 1973-74 | (1493) | (845) | 472 | 2580 | 1844 | 1031 | 440 | 0 | 0 | 0 | (756) | (2439) |
| 1974-75 | (2282) | (1378) | 2660 | 2364 | 217 | 0 | 353 | 121 | 1157 | 0 | 0 | (2440) |
| 1975-76 | (987) | (1378) | 2373 | 314 | 2005 | 43 | 0 | 0 | 0 | 0 | 0 | (2439) |
| 1976-77 | (2440) | (1378) | 548 | 3283 | 100 | 0 | 238 | 419 | 252 | 0 | (756) | (2440) |
| 1977-78 | (2440) | (804) | 0 | 205 | 260 | 0 | 0 | 363 | 3696 | 2346 | 1329) | (2336) |
| 1978-79 | (2439) | (1378) | 924 | 20 | 1935 | 830 | 207 | 758 | 546 | 0 | (399) | (2366) |
| 1979-80 | (2340) | (1024) | 237 | 9 | 2100 | 1033 | 1210 | 756 | 995 | 1209 | (458) | (2440) |
| 1980-81 | (2439) | (1164) | 1601 | 0 | 2343 | 1432 | 0 | 100 | 467 | 186 | (757) | (2439) |
| 1981-82 | (2440) | (662) | 517 | 251 | 1596 | 1407 | 1194 | 1352 | (3) | 0 | 0 | (2439) |
| 1982-83 | (1697) | (356) | 1990 | 850 | 1048 | 504 | 0 | 88 | 0 | 0 | (756) | (1712) |
| 1983-84 | (785) | (1378) | 2421 | 957 | 1112 | 59 | 7 | 0 | 0 | 0 | (756) | (2055) |
| 1984-85 | (648) | (1378) | 2438 | 502 | 649 | 150 | 173 | 174 | 485 | 217 | (756) | (2439) |
| 1985-86 | (2339) | (1033) | 1426 | 1292 | 625 | 1368 | 604 | 1190 | 0 | 0 | (757) | (2439) |
| 1986-87 | (2289) | (1003) | 3252 | 1561 | 34 | 0 | 0 | 0 | 0 | 100 | (656) | (2439) |
| 1987-88 | (2440) | (1378) | 0 | 23 | 37 | 0 | 70 | 0 | 0 | 0 | (756) | (2059) |
| 1988-89 | (2440) | (1364) | 962 | 790 | 60 | 200 | 0 | 0 | 5984 | 1288 | (376) | (1969) |

Note: Minus is a release from storage.

2,406.9 m³/s (85,000 cfs), then there was no spill at Little Goose and Lower Monumental; otherwise, spill was 80 and 81 percent of regulated flow at Little Goose and Lower Monumental, respectively. Bonneville had a daytime spill cap of 2,123.8 m³/s (75,000 cfs) from 0600 to 1800 hours. Juvenile Bypass Fish Spill at Federal projects (in percent of regulated flow), limited by Spill Caps, is shown in Table 4-7. The spill caps represent completed modifications at spillways currently planned and which are used as hydroregulation modeling caps, not instantaneous.

**Table 4-7.** Juvenile Bypass Fish Spill (Percent of Regulated Flow) and Spill Cap (cfs) – Federal Projects

| | MAR | APR1 | APR 2 | MAY | JUN | JUL | AUG1 | AUG 2 | CAP (cfs) | CAP ($m^3/s$) |
|---|---|---|---|---|---|---|---|---|---|---|
| Bonneville | 23.0 | | 49.9 | 68.0 | 68.0 | 77.0 | 77.0 | 77.0 | 100,000 | 2,831.7 |
| The Dalles | | | 46.9 | 64.0 | 64.0 | 64.0 | 64.0 | 64.0 | 230,000 | 6,512.9 |
| John Day | | | 12.1 | 16.5 | 16.5 | 43.0 | 43.0 | 43.0 | 60,000 | 1,699 |
| Ice Harbor | | 10.8 | 27.0 | 27.0 | 41.3 | 70.0 | 70.0 | 70.0 | 60,000 | 1,699 |
| McNary | | | 18.3 | 25.0 | 25.0 | | | | 60,000 | 1,699 |
| Lower Monumental | | 16.2 | 40.5 | 40.5 | 27.0 | | | | 20,000 | 566.3 |
| Little Goose | | 16.0 | 40.0 | 40.0 | 26.7 | | | | 25,000 | 707.9 |
| Lower Granite | | 16.0 | 40.0 | 40.0 | 26.7 | | | | 22,500 | 637.1 |

BPA used spill caps as submitted by the Corps in OY97 PNCA planning which differed from this table at The Dalles [5,380.2 m³/s (190,000 cfs)], John Day [1,699.0 m³/s (6,000 cfs)], and McNary [1,982.2 m³/s (70,000 cfs)].]

#### 4.2.4.8 Juvenile Bypass Fish Spill at Non-Federal Projects

Generation was also reduced for juvenile bypass spill at non-Federal projects. The percent of regulated flow and spill caps is described in Table 4-8 and was submitted for operating year 1996-97 PNCA planning. Rock Island spill is described in cfs.

### 4.2.5 BPA Operational Step

#### 4.2.5.1 Loads and Secondary Market

BPA used PNCA firm Loads based on operating year 1998 projections made by the Marketing Analysis, Bulk Power Marketing Branch, were used in the Operational Step. A 9,000 aMW secondary load limit was used in every period of every year.

#### 4.2.5.2 Variable Energy Content Curve

BPA used VECCs that were calculated using OY97 PDRs. Although VECC lower limits were eliminated from OY97 refill studies, a lower limit of 379.5 m (1,245 ft) in January, 371.9 m (1,220 ft) for February through April, 378 m (1,240 ft) in May, and 391.7 m (1,285 ft) in June at Grand Coulee was used in calculating the VECC during period in which the system is generating surplus energy. The Canadian AOP VECCs were based on historical volumes. The VECCs for the Federal projects were based on the Kuehl Moffitt volume forecasts.

**Table 4-8.** Juvenile Bypass Fish Spill (Percent of Regulated Flow) and Spill Cap (cfs) – Non-Federal Projects

| PROJECTS: | APR1 | APR 2 | MAY | JUN | JUL | AUG1 | CAP (cfs) | CAP ($m^3/s$) |
|---|---|---|---|---|---|---|---|---|
| Wells | 0.0 | 6.5 | 6.5 | 0.0 | 6.5 | 2.5 | 10,000 | 283.2 |
| Rocky Reach | 0.0 | 12.0 | 15.0 | 4.0 | 8.0 | 4.0 | 5,000 | 141.6 |
| Wanapum | 0.0 | 10.0 | 25.0 | 2.5 | 14.2 | 20.0 | 10,000 | 283.2 |
| Priest Rapids | 0.0 | 7.0 | 35.0 | 5.8 | 13.5 | 20.0 | 25,000 | 707.9 |

| Rock Island | PERIOD AVERAGE SPILL (cfs) | PERIOD AVERAGE SPILL ($m^3/s$) |
|---|---|---|
| April 1-15 | 4,800 | 135.9 |
| April 16-30 | 19,300 | 546.5 |
| May | 23,000 | 651.3 |
| June | 23,000 | 651.3 |
| July | 23,000 | 651.3 |
| August 1-15 | 19,300 | 546.5 |
| August 16-31 | 4,800 | 135.9 |

### 4.2.5.3 Libby Project Operation

BPA operated Libby in the same manner as in the AER step with the following exceptions. Libby was operated mid-April through July for protection of sturgeon in all but 20 percent of the driest years (see Table 4-9, Libby Sturgeon Flow Objective, for years which no releases are provided) by meeting Bonners Ferry minimum flows. Sturgeon Flow Objectives included May 1 through May 9, minimum flow at Bonners Ferry is 424.8 $m^3/s$ (15,000 cfs); May 10 through June 20, Libby outflow reflects a full turbine operation; June 21 through July 11, minimum flow at Bonners Ferry is 311.5 $m^3/s$ (11,000 cfs). The following table (Table 4-9) shows the computed Libby outflow required in the years when sturgeon releases were provided (assuming project discharge during a full turbine operation was equal to 707.9 $m^3/s$ (25,000 cfs). If the reservoir was above 743.4 m (2,439 ft), the project discharged up to powerhouse capacity, without spill, to support the McNary flow augmentation objectives.

### 4.2.5.4 Grand Coulee Project Operation

BPA operated Grand Coulee's during the September through December period the same as in the AER step. Grand Coulee was operated for power but no lower than the Biological Rule Curves as implemented in the AER January through mid-April. Grand Coulee was operated as low as 381 m (1,250.0 ft) [283.5 khm (1,159.1 ksfd)] in the second half of April and as low as 390.1 m (1,280.0 ft) or flood control [542.1 khm (2,216.4 ksfd)] in May through August to try to meet the McNary flow augmentation objectives. At-site minimum flow was 1,415.8 $m^3/s$ (50,000 cfs) for peaking purposes.

### 4.2.5.5 Juvenile Bypass Fish Spill at Federal Projects

Juvenile bypass fish spill at Federal projects were the same as the AER Step, except the cap was adjusted as shown below in Table 4-10.

**Table 4-9.** Libby Sturgeon Flow Objectives

| | May | June | July | | May | June | July |
|---|---|---|---|---|---|---|---|
| 1929 | No | No | No | 1954 | 18903 | 18000 | 4000 |
| 1930 | No | No | No | 1955 | 18903 | 18000 | 4810 |
| 1931 | No | No | No | 1956 | 18903 | 18000 | 5101 |
| 1932 | 18903 | 18000 | 5312 | 1957 | 18903 | 18256 | 5770 |
| 1933 | 18903 | 18000 | 4245 | 1958 | 18903 | 19133 | 5985 |
| 1934 | 18903 | 18436 | 5760 | 1959 | 18903 | 18000 | 5038 |
| 1935 | 18903 | 18000 | 5315 | 1960 | 18903 | 18000 | 5504 |
| 1936 | No | No | No | 1961 | 18903 | 18000 | 5590 |
| 1937 | 18903 | 18000 | 5592 | 1962 | 18903 | 18000 | 5723 |
| 1938 | 18903 | 18000 | 5283 | 1963 | 19023 | 18000 | 5529 |
| 1939 | No | No | No | 1964 | 18903 | 18000 | 5345 |
| 1940 | 19660 | 19124 | 6165 | 1965 | 18903 | 18000 | 5435 |
| 1941 | No | No | No | 1966 | 18903 | 18000 | 5379 |
| 1942 | 19094 | 18000 | 4784 | 1967 | 18903 | 18000 | 5489 |
| 1943 | 18903 | 18000 | 4596 | 1968 | 18903 | 18000 | 5465 |
| 1944 | No | No | No | 1969 | 18903 | 18000 | 4890 |
| 1945 | 18903 | 18108 | 5803 | 1970 | No | No | No |
| 1946 | 18903 | 18000 | 5244 | 1971 | 18903 | 18000 | 4448 |
| 1947 | 18903 | 18000 | 5676 | 1972 | 18903 | 18000 | 5484 |
| 1948 | 18903 | 18000 | 5052 | 1973 | 20018 | 19407 | 6268 |
| 1949 | 18903 | 18413 | 5951 | 1974 | 18903 | 18000 | 4431 |
| 1950 | 18903 | 18000 | 4117 | 1975 | 18903 | 18000 | 5464 |
| 1951 | 18903 | 18000 | 5311 | 1976 | 18903 | 18240 | 5201 |
| 1952 | 18903 | 18000 | 5126 | 1977 | No | No | No |
| 1953 | 18903 | 18000 | 5449 | 1978 | 18903 | 18324 | 5465 |

**Table 4-10.** Federal Project Spill Caps

| Project | CAP ($m^3/s$) | CAP (cfs) |
|---|---|---|
| Bonneville | 2,831.7 | 100,000 |
| The Dalles | 6,512.9 | 230,000 |
| John Day | 1,699.0 | 60,000 |
| Ice Harbor | 1,699.0 | 60,000 |
| McNary | 1,699.0 | 60,000 |
| Lower Monumental | 566.3 | 20,000 |
| Little Goose | 707.9 | 25,000 |
| Lower Granite | 637.1 | 22,500 |

## 4.3 Alternative A2

Alternative A2 is a continuous study of the system operations under a scenario where the Base Condition (Alternative A1) spill was adjusted without drawdown of the Lower Snake River or John Day reservoirs. The alternative relies on fish transportation as the primary method for fish passage and assumes the current level of development of fish facilities. This alternative eliminates fish spill at Lower Granite, Little Goose, Lower Monumental and McNary, the fish transportation projects.

### 4.3.1 System Demand

The loads and secondary market limit used in this alternative were the same as Alternative A1, see Section 4.2.1.

### 4.3.2 Rule Curves

The flood control rule curves, Variable Energy Content Curves and Critical Rule Curves used in this alternative were the same as Alternative A1, see Section 4.2.2.

### 4.3.3 Project Operations

Reservoirs were initialized to the same storage content used in Alternative A1. Projects operated to the same non-power requirements used in Alternative A1. Other project operations used in this alternative remained unchanged from Alternative A1, see Section 4.2.3.

### 4.3.4 System Operations

The McNary, Lower Granite, and Vernita Bar flow augmentation objectives used in this alternative were the same as Alternative A1. Upper Snake flow augmentation used in this alternative was the same as Alternative A1. The four Lower Columbia projects and the Lower Snake River Project continued to operate within 1 percent of peak efficiency. The minimum pool operation at the Lower Snake River Project remained unchanged. Spill for juvenile bypassing remained the same as Alternative A1 at non-Federal projects, but changed at the Federal projects. Spill at collector facilities such as Lower Granite, Little Goose, Lower Monumental, and McNary is removed. For the spill requirements at Bonneville, The Dalles, John Day, and Ice Harbor, see Section 4.2.4. A description of other system operations are found in Section 4.2.4.

### 4.3.5 BPA Operational Step

The loads, secondary market and Variable Energy Content Curves used in this alternative were the same as Alternative A1. The Libby and Grand Coulee project operations used in this alternative were the same as Alternative A1. Spill at collector projects such as Lower Granite, Little Goose, Lower Monumental, and McNary was removed. For the spill requirements at Bonneville, The Dalles, John Day, and Ice Harbor, see Section 4.2.5.5. Other requirements for the BPA Operational Step are described in Section 4.2.5.

## 4.4 Alternative A3

Alternative A3 is a continuous study of the system operations under a scenario where the Base Condition (Alternative A1) was adjusted only for drawdown of Lower Granite, Little Goose, Lower Monumental, and Ice Harbor, to natural river levels. Flow augmentation requirements on the Snake and Columbia rivers were not changed. It was assumed that non-Federal owners would remove their

reservoirs from planning, thereby not requiring them to draft to meet load. Non-Federal projects were fixed on the operation resulting from the Base Condition regulation. Federal projects were allowed to pick up as much of the load lost from removing the lower Snake plants while still meeting project non-power requirements.

### 4.4.1 System Demand

The loads and secondary market limit used in this alternative were the same as Alternative A1, see Section 4.2.1.

### 4.4.2 Rule Curves

The flood control rule curves, Variable Energy Content Curves and Critical Rule Curves used in this alternative were the same as Alternative A1, see Section 4.2.2.

### 4.4.3 Project Operations

Reservoirs were initialized to the same storage content used in Alternative A1. Projects operated to the same non-power requirements used in Alternative A1. Other project operations used in this alternative remained unchanged from Alternative A1, except at the Lower Snake River Project which was drawn down to natural river. For a description of project operations see Section 4.2.3.

### 4.4.4 System Operations

The McNary, Lower Granite, and Vernita Bar flow augmentation objectives used in this alternative were the same as Alternative A1. Upper Snake flow augmentation used in this alternative was the same as Alternative A1. The Lower Snake River Project was drawn down to natural river, therefore, generation at these plants was eliminated and efficiency requirements no longer apply. The Lower Snake River Project MOP operation was removed. In addition, fish spill at these plants no longer applies. Spill at other Federal and Non-Federal plants remains unchanged. For a description of project operations see Section 4.2.4. For a description of project operations see Section 4.2.4. BPA reflected this requirement in the hydropower availability file which limited the maximum generation capability of the Lower Snake River Project in each of the 14 periods to zero.

### 4.4.5 BPA Operational Step

The loads, secondary market and Variable Energy Content Curves used in this alternative were the same as Alternative A1. The Libby and Grand Coulee project operations used in this alternative were the same as Alternative A1. The Lower Snake River Project was drawn down to natural river levels, therefore spill for fish, operation within 1 percent of peak efficiency, and the MOP operation no longer apply. Other requirements for the BPA Operational Step are described in Section 4.2.5.

## 4.5 Alternative A5

Alternative A5 is a continuous study of the system operations under a scenario where the Base Condition (Alternative A1) was adjusted for the drawdown of the Lower Snake River Project to natural river level and to remove flow augmentation at Lower Granite. The upper Snake River flow augmentation was removed. It was assumed that non-Federal owners would remove their reservoirs from planning, thereby not requiring them to draft to meet load. Non-Federal projects were fixed on the operation resulting from the Base Condition regulation. Federal projects were allowed to pick

up as much of the load lost from removing the Lower Snake plants while still meeting project non-power requirements. Dworshak operation was allowed to meet FELCC September through May, observing a summer recreation requirement to be above elevation 486.2 m (1,595 ft).

### 4.5.1 System Demand

The loads and secondary market limit used in this alternative were the same as Alternative A1, see Section 4.2.1.

### 4.5.2 Rule Curves

Dworshak and Brownlee projects provide both system and local flood control space in their reservoirs during the flood control evacuation period. To allow these projects to store more water for flow augmentation purposes, the system flood control requirement at these two projects were shifted to Grand Coulee project. This was done when the April-July volume forecasts are less than 394.7 khm (3.2 MAF) and 715.4 khm (5.8 MAF), respectively. The flood control used in this alternative was the same as Alternative A1 (see Section 4.2.2), except the system flood control was not shifted to Grand Coulee because the Snake River flow augmentation requirement was removed.

The Variable Energy Content Curves and Critical Rule Curves used in this alternative were the same as Alternative A1, see Section 4.2.2.

### 4.5.3 Project Operations

Reservoirs were initialized to the same storage content used in Alternative A1, with the exception of Dworshak that was initialized to elevation 487.7 m (1,600 ft). Projects were operated to the same non-power requirements used in Alternative A1. Other project operations used in this alternative remained unchanged from Alternative A1, except at Dworshak and Brownlee.

Dworshak was allowed to meet FELCC September 1 through May 31. Dworshak was limited to a discharge of 707.9 $m^3/s$ (25,000 cfs) for flood control. For recreation during June through August, the reservoir was held to above elevation 486.2 m (1,595 ft). In October, the maximum discharge is equal to inflow plus 36.8 $m^3/s$ (1,300 cfs). There are no draft limits or 85 percent confidence of reaching flood control on April 20.

Brownlee was operated to meet FELCC. The operation had flood control, 566.3 $m^3/s$ (20,000 cfs) maximum flow in October and 254.9 $m^3/s$ (9,000 cfs) maximum flow in November imposed over the fixed operation used in PNCA planning.

### 4.5.4 System Operations

The McNary and Vernita Bar flow augmentation objectives used in this alternative were the same as Alternative A1. The Lower Granite flow augmentation objectives was removed. The Upper Snake reservoir operations was adjusted to release 52.7 khm (427 KAF). The Lower Snake River Project was drawn down to natural river, therefore, generation at these plants were eliminated and efficiency requirements no longer apply. The Lower Snake River Project MOP operation was removed and fish spill at these plants no longer applies. Spill at other Federal and Non-Federal plants remained unchanged.

### 4.5.5 BPA Operational Step

The loads and secondary market used in this alternative were the same as Alternative A1.

Although VECC lower limits were eliminated from OY97 refill studies, a lower limit of 379.5 m (1,245 ft) in January, 371.9 m (1,220 ft) in February through April, 378.0 m (1,240 ft) in May, and 391.7 m (1,285 ft) in June at Coulee was used in calculating the VECC during periods in which the system was generating surplus energy. The Canadian AOP VECCs were based on historical volumes and the Arrow Total method. The VECCs for the Federal projects were based on the Kuehl Moffitt volume forecasts.

Libby was operated in the same manner as in the AER studies with the following exceptions. Libby was operated mid-April through July for protection of sturgeon in all but 20 percent of the driest years (see Flow Objective Table 4-9 for years when no releases were provided) by meeting Bonners Ferry minimum flows. Sturgeon objectives included May 1 through 9, minimum flow at Bonners Ferry was 424.8 $m^3/s$ (15,000 cfs); May 10 through June 20, Libby outflow reflected a full turbine operation; June 21 through July 11, minimum flow at Bonners Ferry was 311.5 $m^3/s$ (11,000 cfs). The table shows the computed Libby outflow required in the years when sturgeon releases were provided (assuming project discharge during a full turbine operation is equal to 707.9 $m^3/s$ [25,000 cfs]). If the reservoir was above 743.4 m (2,439 ft), the project discharged up to powerhouse capacity, without spill, to support the McNary flow augmentation objective.

Grand Coulee's operation during the September through December period was the same as in the AER step. Grand Coulee was operated for power but no lower than the Biological Rule Curves as implemented in the AER January through mid-April. Grand Coulee was operated as low as 381.0 m (1,250.0 ft) [283.5 khm (1,159.1 ksfd)] in the second half of April and as low as 390.1 m (1,280.0 ft) or flood control [542.1 khm (2,216.4 ksfd)] in May through August to try to meet the McNary flow augmentation objective. At-site minimum flow was 1,415.8 $m^3/s$ (50,000 cfs) for peaking purposes.

## 4.6 Alternative A6a

Alternative A6a is a continuous study of the system operations augmentation of an additional 176 khm (1 MAF) (1,427 KAF total) over the Base Condition (Alternative A1) from the upper Snake River. Priority to refill by June 30 for biological purposes was provided by reducing the flow augmentation objectives in low water years on the Snake River at Lower Granite.

### 4.6.1 System Demand

The loads and secondary market limit used in this alternative were the same as Alternative A1 (see Section 4.2.1).

### 4.6.2 Rule Curves

The flood control rule curves, Variable Energy Content Curves and Critical Rule Curves used in this alternative were the same as Alternative A1 (see Section 4.2.2).

### 4.6.3 Project Operations

Reservoirs were initialized to the same storage content used in Alternative A1. Projects were operated to the same non-power requirements used in Alternative A1. Other project operations used in this alternative remained unchanged from Alternative A1 (see Section 4.2.3).

### 4.6.4 System Operations

The McNary and Vernita Bar flow augmentation objectives used in this alternative were the same as Alternative A1. Lower Granite sliding scale flow augmentation objectives were lowered during low flow years to assist reservoir refill by June 30. For spring flow objective (10 April to 20 June), when the April 1, April through July runoff forecast is less than 1,233.5 khm (10 MAF), the project was operated on minimum flow or URC except in May where the Lower Granite objective was 1,699 $m^3/s$ (60,000 cfs). For spring flows when the forecast is 1,233.5 khm (10 MAF) to 1,973.6 khm (16 MAF), April and June operation was on minimum flow or URC. The May flow objective ranged, on a sliding scale, from 1,699 $m^3/s$ (60,000 cfs) to 2,406.9 $m^3/s$ (85,000 cfs). For spring flows when the forecast was 1,973.6 khm (16 MAF) to 2,467.0 khm (20 MAF), flow objective ranged, on a sliding scale, from 2,406.9 $m^3/s$ (85,000 cfs) to 2,831.7 $m^3/s$ (100,000 cfs). When forecast was greater than 2,467.0 khm (20 MAF), then the mid-April through June 20 flow objective was 2,831.7 $m^3/s$ (100,000 cfs). For summer flow objective (21 June through August), when the forecast was less than 1,973.6 khm (16 MAF), the flow objective was 1,415.8 khm (50,000 cfs). For summer, when the forecast was 1,973.6 khm (16 MAF) to 3,453.8 khm (28 MAF), flow objectives ranged from 1,415.8 khm (50,000 cfs) to 1,557.4 $m^3/s$ (55,000 cfs). For summer when the forecast was greater than 3,453.8 khm (28 MAF), flow objective was 1,557.4 $m^3/s$ (55,000 cfs).

Upper Snake flow augmentation used in this alternative was increased to 176.0 khm (1,427 KAF), 123.3 khm (1 MAF) over the Base Condition. The Upper Snake reservoir operations adjustments to Brownlee inflows came from the BoR in June 1998. The operation tries to release 176.0 khm (1,427 KAF) in as many years as possible over the 60-year record during the May through August period. Adjustments were made based on the "Reservoir Emphasis" alternative. The reservoir emphasis alternative utilized irrigation, thereby protecting Upper Snake River reservoirs. BPA used 50 years of these data. See Table 4-11.

The four Lower Columbia projects and the Lower Snake River Project continued to operate within 1 percent of peak efficiency. The minimum pool operation at the Lower Snake River Project remained unchanged. Spill for juvenile bypassing remained the same as Alternative A1 at non-Federal projects and at the Federal projects.

A description of other system operations that were unchanged is found in Section 4.2.4.

### 4.6.5 BPA Operational Step

The Operational Step was run by BPA. All project operations were modeled as in the AER step except as specifically addressed below. PNCA firm Loads based on OY98 projections by the Marketing Analysis, Bulk Power Marketing Branch were used in this study. A limited secondary market of 9,000 a MW was used in every period, every year.

VECCs were calculated using OY97 PDRs. Although VECC lower limits were eliminated from OY97 refill studies, a lower limit of 379.5 m (1,245 ft) in January, 371.9 m (1,220 ft) February through April, 378.0 m (1,240 ft) in May, and 391.7 m (1,285 ft) in June at Coulee was used in calculating the VECC during period in which the system was generating surplus energy. The Canadian AOP VECCs were based on historical volumes and the Arrow Total method. The VECCs for the Federal projects were based on the Kuehl Moffitt volume forecasts.

**Table 4-11.** Upper Snake River Flow Augmentation (cfs)

| | AUG | SEP | OCT | NOV | DEC | JAN | FEB | MAR | AP2 | MAY | JUN | JUL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1929 | (13803) | 467 | 292 | 1634 | 311 | 246 | 220 | 644 | 315 | (331) | 1174 | (251) |
| 1930 | 342 | 858 | 515 | 373 | 1846 | 283 | (221) | 320 | 310 | (11563) | (9117) | (97) |
| 1931 | 484 | 226 | 224 | 296 | 293 | 227 | 220 | 198 | 700 | (11452) | (9391) | 120 |
| 1932 | (17567) | 1365 | 803 | 511 | 369 | 366 | 312 | (44 | (464) | 145 | (916) | (388) |
| 1933 | (10005) | 1132 | 439 | 389 | 352 | 285 | 69 | 346 | 4525 | (3431) | 184 | (438) |
| 1934 | 259 | 674 | 492 | 300 | 319 | 118 | 152 | 413 | 534 | (22488) | (465) | (315) |
| 1935 | (381) | 1178 | 695 | 365 | 398 | 52 | 298 | 201 | (773) | (8758) | (3667) | (3333) |
| 1936 | (837) | 958 | 574 | 623 | 354 | 392 | 184 | (1086) | 579 | (1659) | (11804) | (6148) |
| 1937 | 151 | 457 | 558 | 421 | 352 | 1059 | 225 | 1247 | 641 | 270 | (15437) | (5548) |
| 1938 | (17801) | 101 | 806 | 409 | 526 | 1995 | 772 | 5331 | (2355) | 1806 | (1925) | (411) |
| 1939 | 28 | 79 | 353 | 6013 | 2585 | 304 | 185 | (539 | 1419 | 556 | (22309) | (226) |
| 1940 | 25 | 758 | 661 | 453 | 336 | 285 | 614 | 1575 | 2265 | 1990 | (13957) | (7368) |
| 1941 | 12 | 417 | 248 | 349 | 356 | 173 | 302 | 272 | 1624 | (5010) | (6415) | (6914) |
| 1942 | (17111) | 539 | 176 | 745 | 1687 | 1820 | 231 | 1063 | 7374 | 1167 | (2525) | (313) |
| 1943 | (9045) | 462 | 70 | 374 | (718) | 6439 | (1202) | 2195 | (2717) | 218 | (85) | (317) |
| 1944 | 35 | 212 | 3522 | 437 | 318 | 316 | 310 | 311 | 299 | (8696) | (7906) | (1434) |
| 1945 | (17650) | 507 | 183 | 372 | 4221 | 325 | 327 | 295 | 846 | 2515 | 176 | (106) |
| 1946 | (16363) | 566 | 7500 | 1266 | 321 | 182 | 1554 | 2450 | (3055) | (421) | (1927) | (136) |
| 1947 | (17566) | 568 | 308 | 4224 | 1045 | 389 | 333 | 3902 | 1088 | (1141) | (938) | (733) |
| 1948 | (8560) | 877 | 120 | 6084 | 958 | 523 | 329 | 117 | 764 | 93 | (134) | (468) |
| 1949 | (9764) | 221 | (1492) | 673 | 504 | 111 | 332 | (160) | 583 | 449 | (5437) | (3313) |
| 1950 | (8713) | 739 | 1343 | 401 | 533 | 927 | (46) | 2303 | 1656 | 1065 | (1242) | (112) |
| 1951 | (15946) | 2600 | 1322 | 638 | 665 | 108 | 1176 | 1025 | (3061) | 79 | (81) | (516) |
| 1952 | (17343) | 48 | 6891 | 1891 | 896 | 788 | 339 | 3193 | 897 | 110 | (1034) | (523) |
| 1953 | (8704) | 270 | 107 | 3856 | 1329 | 330 | 134 | 1848 | 311 | 1086 | (880) | (353) |
| 1954 | (10212) | 349 | 1228 | 426 | 418 | 303 | (386) | 966 | 310 | (800) | (387) | (731) |
| 1955 | (8892) | 783 | 222 | 2534 | 1189 | 298 | 310 | 315 | 1318 | 1844 | (595) | (323) |
| 1956 | (17604) | 67 | 168 | 434 | (1475) | 1188 | (2353) | 198 | (1033) | (94) | (1120) | (582) |
| 1957 | (17508) | 215 | 4219 | 3678 | 336 | 210 | 704 | 3207 | 334 | (161) | (447) | (1049) |
| 1958 | (17306) | 633 | 2906 | 5266 | 213 | 331 | 1891 | 1151 | (3049) | 1138 | (231) | (706) |
| 1959 | (12739) | 1163 | 305 | 563 | 3425 | 919 | 165 | (627) | 5558 | (4240) | (1605) | (642) |
| 1960 | (8528) | 821 | 205 | 1064 | 1038 | 332 | 310 | 345 | 302 | (7490) | (995) | (466) |
| 1961 | (4033) | 557 | 530 | 458 | 358 | 246 | 360 | 43 | 268 | (5148) | (1085) | (6607) |
| 1962 | (7067) | 487 | 231 | 405 | 357 | (99 | (883) | 539 | 244 | (3816) | (897) | (322) |
| 1963 | (14494) | 285 | 894 | 2725 | 2778 | 151 | 332 | (411) | 795 | 159 | 117 | (308) |
| 1964 | (7862) | 465 | 122 | 507 | 2747 | 335 | 328 | (825) | 1596 | 201 | 179 | (491) |
| 1965 | (2518) | 559 | 828 | 638 | (811) | 1081 | (380 | 1038 | (1030) | (194) | (1722) | (356) |
| 1966 | (9) | 678 | (125) | 317 | 305 | 302 | 324 | 291 | 504 | (13874) | (6947) | (385) |
| 1967 | (13713) | 153 | 140 | 412 | 359 | 1373 | 1549 | 1361 | 4061 | (2268) | 398 | (653) |
| 1968 | (8527) | 352 | 5891 | 853 | 465 | 313 | 326 | 279 | 882 | (5731) | (1491) | (305) |
| 1969 | (17239) | 3231 | 3878 | 352 | 409 | 717 | (69) | 817 | (2216) | 736 | (1212) | (646) |
| 1970 | (9572) | 826 | 1476 | 4267 | 449 | 713 | (302 | 1028 | 236 | 2850 | (1550) | (607) |
| 1971 | (6631) | 2487 | 459 | 1013 | 481 | 2032 | (376 | 1042 | (1032) | 358 | (1998) | (608) |
| 1972 | (9773) | 4699 | 410 | 373 | 367 | 142 | 1675 | 621 | 1574 | (1509) | (186) | (645) |
| 1973 | (411) | 5360 | 597 | 355 | 295 | 299 | 328 | 51 | 275 | (1147) | (17178) | (240) |
| 1974 | (5800) | 437 | 7438 | 630 | 948 | 2394 | 136 | 2296 | (1032) | 1562 | (2381) | (787) |
| 1975 | (4114) | 2151 | 748 | 400 | 320 | (417) | 334 | 592 | (549) | 1892 | (116) | (729) |
| 1976 | (5022) | 2460 | 600 | 345 | 302 | 257 | (195) | 123 | 301 | 289 | (215) | (396) |
| 1977 | 536 | 2367 | 915 | 406 | 204 | 299 | 311 | 313 | (2802) | (18798) | 635) | 482) |
| 1978 | (9183) | 786 | 668 | 507 | 357 | 266 | (579) | (3167) | (855) | 43 | 42 | (243) |
| 1979 | (7192) | 731 | 3931 | 717 | 435 | 320 | 332 | 54 | 425 | 674 | (1217) | (8272) |
| 1980 | (12396) | 648 | 209 | 517 | 2438 | 95 | 334 | 3820 | (2491) | 1085 | (1100) | (1250) |
| 1981 | (16408) | 1053 | 61 | 3528 | 1310 | 609 | 610 | 368 | 672 | 1733 | (1879) | (1413) |
| 1982 | (7301) | 1047 | 189 | 871 | 1074 | 1550 | 1008 | 996 | (1018) | 174 | (1193) | (747) |
| 1983 | (3677) | 4699 | 850 | (22) | 296 | 1348 | 1304 | 183 | (108) | (173) | (349) | (234) |
| 1984 | (3362) | 2724 | (271) | 400 | 779 | 632 | 1610 | 617 | 896 | (259) | (1982) | (470) |
| 1985 | (623) | 1620 | 341 | 681 | 28 | 312 | 2 | 791 | 280 | 1752 | (6997) | (10875) |
| 1986 | (13303) | 1491 | (52) | 3306 | 1470 | (1620) | 1630 | 622 | 5108 | (2652) | (186) | (2340) |
| 1987 | 158 | 5933 | 2033 | 419 | 318 | 312 | 329 | 295 | 323 | (9240) | (11017) | 659) |
| 1988 | 380 | 573 | 622 | 449 | 364 | 312 | 289 | 2100 | 295 | (4062) | (16699) | (102) |
| 1989 | (5342) | 870 | 538 | 440 | 367 | 152 | 306 | (2652) | 97 | (837) | (6193) | (3590) |

Notes: minus is a release from storage
1,427 KAF Reservoir Emphasis Data

Libby was operated in the same manner as in the AER studies with the following exceptions. Libby was operated mid-April through July for protection of sturgeon in all but 20 percent of the driest years (see Flow Objective Table 4-9 for years when no releases were provided) by meeting Bonners Ferry minimum flows. Sturgeon objectives included May 1 through May 9, minimum flow at Bonners Ferry was 424.8 $m^3/s$ (15,000 cfs); May 10 through June 20, Libby outflow reflected a full turbine operation; June 21 through July 11, minimum flow at Bonners Ferry was 311.5 $m^3/s$ (11,000 cfs). The table shows the computed Libby outflow required in the years when sturgeon releases were provided (assuming project discharge during a full turbine operation was equal to 707.9 $m^3/s$ [25,000 cfs]). If the reservoir was above 743.4 m (2,439 ft), the project discharged up to powerhouse capacity, without spill, to support the McNary flow augmentation objective.

Grand Coulee's operation during the September through December period was the same as in the AER step. Grand Coulee was operated for power but no lower than the Biological Rule Curves as implemented in the AER January through mid-April. Grand Coulee was operated as low as 381.0 m (1,250.0 ft) [283.5 khm (1,159.1 ksfd)] in the second half of April and as low as 390.1 m (1,280.0 ft) or flood control [542.1 khm (2,216.4 ksfd)] in May through August to try to meet the McNary flow augmentation objective. At-site minimum flow was 1,415.8 $m^3/s$ (50,000 cfs) for peaking purposes.

Juvenile bypass fish spill at Federal projects was the same as the AER Step, except that the cap was adjusted as shown below.

| | **CAP (cfs)** | **CAP ($m^3/s$)** |
|---|---|---|
| BON 320 | 100,000 | 2,831.7 |
| TDA 365 | 230,000 | 651.3 |
| JDA 440 | 60,000 | 1,699.0 |
| IHR 502 | 60,000 | 1,699.0 |
| MCN 488 | 60,000 | 1,699.0 |
| LMN 504 | 20,000 | 566.3 |
| LGS 518 | 25,000 | 707.9 |
| LWG 520 | 22,500 | 637.1 |

## 4.7 Alternative A6b

Alternative A6b is a continuous study of the system operations under the Base Condition (Alternative A1) with no flow augmentation from the upper Snake River. The 52.7 khm (427 KAF) (52.7 khm) upper Snake River flow augmentation used in A1 was removed. Columbia River and Snake River flow augmentation objectives were retained. Priority to refill by June 30 for biological purposes was provided by reducing the flow augmentation objectives in low water years on the Snake River at Lower Granite.

### 4.7.1 System Demand

The loads and secondary market limit used in this alternative were the same as Alternative A1 (see Section 4.2.1).

### 4.7.2 Rule Curves

The flood control rule curves, Variable Energy Content Curves, and Critical Rule Curves used in this alternative were the same as Alternative A1 (see Section 4.2.2).

### 4.7.3 Project Operations

Reservoirs were initialized to the same storage content used in Alternative A1. Projects were operated to the same non-power requirements used in Alternative A1. Other project operations used in this alternative remained unchanged from Alternative A1 (see Section 4.2.3).

### 4.7.4 System Operations

The McNary and Vernita Bar flow augmentation objectives used in this alternative were the same as Alternative A1. The Lower Granite sliding scale flow augmentation objective was lowered during low flow years to assist reservoir refill by June 30. For spring flow objectives (April 10 to June 20), when the April 1, April through July runoff forecast was less than 1,233.5 khm (10 MAF), the project was operated and on minimum flow or URC except in May where the Lower Granite objective was 1,699.0 $m^3/s$ (60,000 cfs). For spring flows when the forecast is 1,233.5 khm (10 MAF) to 1,973.6 khm (16 MAF), April and June operation will be on minimum flow or URC. The May flow objective ranged, on a sliding scale, from 1,699.0 $m^3/s$ (60,000) to 2,406.9 $m^3/s$ (85,000 cfs). For spring flows when the forecast was 1,973.6 $m^3/s$ (16 MAF) to 2,467.0 khm (20 MAF), flow objectives ranged, on a sliding scale, from 2,406.9 $m^3/s$ (85,000) to 2,831.7 $m^3/s$ (100,000 cfs). When the forecast was greater than 2,467.0 khm (20 MAF), the mid-April through June 20 flow objective was 2,831.7 $m^3/s$ (100,000 cfs). For summer flow objectives (June 21 through August), when the forecast was less than 1,973.6 $m^3/s$ (16 MAF), the flow objective was 1,415.8 $m^3/s$ (50,000 cfs). For summer, when the forecast was 1,973.6 $m^3/s$ (16 MAF) to 3,453.8 khm (28 MAF), flow objective ranged from 1,415.8 $m^3/s$ (50,000) to 1,557.4 $m^3/s$ (55,000 cfs). For summer when the forecast was greater than 3,453.8 khm (28 MAF), flow objective was 1,557.4 $m^3/s$ (55,000 cfs).

Upper Snake flow augmentation used in this alternative was decreased to zero. BPA used 50 years of these data.

The four lower Columbia River projects and the Lower Snake River Project continued to operate within 1 percent of peak efficiency. The minimum pool operation at the Lower Snake River Project remained unchanged. Spill for juvenile bypassing remained the same as Alternative A1 at non-Federal projects and at the Federal projects. A description of other system operations that were unchanged is found in Section 4.2.4.

### 4.7.5 BPA Operational Step

The operational step was performed the same as Alternative A6a, as shown in Section 4.6.5.

## 4.8 Alternative B1

This is a continuous study of the system operations under a scenario where the Base Condition (Alternative A1) is adjusted only for drawdown of the Lower Snake River Project to natural river levels, and John Day is operated at natural river level. It was assumed that non-Federal owners would remove their reservoirs from planning, thereby not requiring them to draft to meet load. Non-Federal projects were fixed on the operation resulting from the Base Condition regulation. Federal

projects were allowed to pick up as much of the load lost from removing the Lower Snake and John Day plants while still meeting project non-power requirements.

### 4.8.1 System Demand

The loads and secondary market limit used in this alternative were the same as Alternative A1, see Section 4.2.1.

### 4.8.2 Rule Curves

Flood control rule curves in this alternative were the same as Alternative A1. Although the John Day project was drawn down to natural river, it was assumed that flood control space would remain, filling only to retain water during a flood event and evacuating as soon as practicable. The Variable Energy Content curves and Critical Rule Curves used in this alternative were the same as Alternative A1, see Section 4.2.2.

### 4.8.3 Project Operations

Reservoirs were initialized to the same storage content used in Alternative A1, except at John Day, which was initialized to natural river level. Projects operated to the same non-power requirements used in Alternative A1. Other project operations used in this alternative remained unchanged from Alternative A1 (see Section 4.2.3).

When John Day project operates at natural river level there is no encroachment of the McNary tailwater by John Day pool. Therefore, a new stage vs. tailwater relationship was used in the "B" series of alternatives (see Table 4-12).

**Table 4-12.** McNary Discharge vs. Stage Relationship Without John Day Encroachment

| Discharge, cfs | $m^3/s$ | Elevation, ft | m |
|---|---|---|---|
| 96,000 | 2,718.4 | 253.4 | 77.2 |
| 200,000 | 5,663.4 | 259 | 78.9 |
| 300,000 | 8,495.1 | 264 | 80.5 |
| 400,000 | 11,326.7 | 267.6 | 81.6 |
| 500,000 | 14,158.4 | 270.7 | 82.5 |
| 600,000 | 16,990.1 | 273.5 | 83.4 |
| 800,000 | 22,653.5 | 278.4 | 84.9 |
| 1,150,000 | 32,564.4 | 285.6 | 87.1 |

### 4.8.4 System Operations

The McNary, Lower Granite, and Vernita Bar flow augmentation objectives used in this alternative were the same as Alternative A1. Upper Snake flow augmentation used in this alternative was the same as Alternative A1. The remaining three lower Columbia projects continued to operate within 1 percent of peak efficiency. Spill for juvenile bypassing remained the same as Alternative A1 at non-Federal and at the Federal projects. Spill at Lower Granite, Little Goose, Lower Monumental, Ice Harbor and John Day was removed. For the spill requirements at Bonneville, The Dalles, and McNary, see Section 4.2.4.7. A description of other system operations is found in Section 4.2.4.

### 4.8.5 BPA Operational Step

All project operations were modeled as in the AER step except as specifically addressed below. PNCA firm Loads based on OY98 projections by the Marketing Analysis, Bulk Power Marketing Branch were used in this study.

A limited secondary market of 9,000 aMW was used in every period, every year.

VECCs were calculated using OY97 PDRs. Although VECC lower limits were eliminated from OY97 refill studies, a lower limit of 379.5 m (1,245 ft) in January; 371.9 m (1,220 ft) February through April; 378.0 m (1,240 ft) in May; and 391.7 m (1,285 ft) in June at Coulee was used in calculating the VECC during period in which the system was generating surplus energy. The Canadian AOP VECCs were based on historical volumes and the Arrow Total method. The VECCs for the Federal projects were based on the Kuehl Moffitt volume forecasts.

Libby was operated in the same manner as in the AER studies with the following exceptions. Libby was operated mid-April through July for protection of sturgeon in all but 20 percent of the driest years (see Flow Objective Table 4-9 for years when no releases were provided) by meeting Bonners Ferry minimum flows. Sturgeon objectives included May 1 through May 9, minimum flows at Bonners Ferry was 424.8 $m^3/s$ (15,000 cfs); May 10 through June 20, Libby outflow reflected a full turbine operation; June 21 through July 11, minimum flow at Bonners Ferry was 311.5 $m^3/s$ (11,000 cfs). The table shows the computed Libby outflow required in the years when sturgeon releases were provided (assuming project discharge during a full turbine operation was equal to 707.9 $m^3/s$ [25,000 cfs]). If the reservoir was above 743.4 m (2,439 ft), the project discharged up to powerhouse capacity, without spill, to support the McNary flow augmentation objectives.

Grand Coulee's operation during the September through December period was the same as in the AER steps. Grand Coulee was operated for power but no lower than the Biological Rule Curves as implemented in the AER January through mid-April. Grand Coulee was operated as low as 381.0 m (1,250.0 ft) 283.5 khm (1,159.1 ksfd) in the second half of April and as low as 390.1 m (1,280.0 ft) or flood control 542.1 khm (2,216.4 ksfd) in May through August to try to meet the McNary flow augmentation objectives. At-site minimum flow was 1,415.5 $m^3/s$ (50,000 cfs) for peaking purposes.

Juvenile bypass fish spill at Federal projects was the same as the AER Step, except that the cap was adjusted as shown below. Lower Snake and John Day spill was removed.

| | CAP (cfs) | $m^3/s$ |
|---|---|---|
| Bonneville | 100,000 | 2,831.7 |
| The Dalles | 230,000 | 6,512.9 |
| McNary | 60,000 | 1,699.0 |

## 4.9 Alternative B2

This alternative is a continuous study of the system operations under a scenario where the Base Condition (Alternative A1) is adjusted for drawdown of the Lower Snake River Project to natural river levels and John Day is operated at natural river level. In this alternative, it was assumed that non-Federal owners would remove their reservoirs from planning, thereby not requiring them to draft to meet load. Non-Federal projects would be fixed on the operation resulting from the

regulation from A1. Flow augmentation on the Columbia River and Snake River was removed, thereby freeing up the reservoir operation for power purposes much of the time. Libby would still provide sturgeon releases. Juvenile bypass spill and 1 percent peak operation is retained. BPA did not model Alternative B2.

### 4.9.1 System Demand

The system demand or load for this alternative was developed from operating year 1981-82 Critical Period study run by the NWPP. The NWPP study had a 4-year critical period (September 1, 1929 through February 28, 1932). This critical period study was prepared before water budget or any flow augmentation and would yield FELCC shape consistent with removing Columbia River and Snake River flow augmentation. The hydroelectric system in 1981-82 was able to support more load than the current system, but the shape was acceptable. To make the system total load consistent with the current load carrying capability, the 1981-82 loads were decremented by 1,422 aMW.

One year of FELCC values was used for all water conditions. This study reflects coordination between PNCA parties in meeting PNCA FELCC. Therefore, generation from projects owned by non-PNCA parties (Brownlee, Oxbow and Hells Canyon) would not be used to meet PNCA FELCC in these studies. FELCC for periods outside the critical period came from the PNCA Final Regulation. FELCC was created by adding Hydropower Independent generation from 1928-29 to compute system total generation. Then, the system total generation was reduced by 60 years of hydro-independent generation to produce 60 years of FELCC. The secondary market limit used in this alternative were the same as Alternative A1 (see Section 4.2.1).

### 4.9.2 Rule Curves

Flood control rule curves in this alternative were the same as Alternative A1, except that the system flood control at Dworshak and Brownlee was not shifted to the Grand Coulee project since Snake River flow augmentation was removed. Although the John Day project was drawn down to natural river, it was assumed that flood control space would remain, filling only to retain water during a flood event and evacuating as soon as practicable.

The Variable Energy Content Curves used in this alternative were calculated using Operating Year 1979-80 PDRs, distribution factors and forecast errors which were used in PNCA planning. Canadian Treaty projects were calculated using AOP97 PDRs, the same as Alternative A1. At Grand Coulee the VECC is limited by the Gifford/Inchelium Ferry minimum operating requirements to elevation 371.9 m (1,220 ft). The volume forecast for all projects was based on actual runoff.

In this alternative the CRC were developed in accordance with PNCA 1982 adopted system critical rule curves and published in the Final Regulation for operating year 1981-82. The first year critical curves came from Operating Year 1981-82. The second year critical rule curves came from Operating Year 1980-81, CRC2. The third year critical rule curves came from Operating Year 1979-80, CRC4. The fourth year critical rule curves were set to empty.

### 4.9.3 Project Operations

Storage reservoirs were initialized to the same elevations as Alternative A1 except Grand Coulee, Hungry Horse, Libby, and Dworshak, which were initialized to elevations 393.2 m (1,290 ft) [639.5 khm (2,614.4 ksfd)]; 1,085.1 m (3,560 ft); 749.5 m (2,459 ft) [614.1 khm (2,510.5 ksfd)]; and 487.7 m (1,600 ft) [248.5 khm (1,016.0 ksfd)], respectively. John Day was initialized to natural river

level. Projects were operated to the same non-power requirements used in Alternative A1, except as noted below. See Section 4.2.3 for a description of other reservoirs.

Libby was operated in proportional draft during September through December to meet December's URC of elevation 734.9 m (2,411.0 ft) [367.4 khm (1,502.2 ksfd)]. In January through mid-April, Libby was operated on minimum flow or flood control. It should be noted that Libby does violate URC to allow Corra Linn's maximum lake level not to exceed the IJC 1938 Order. Libby was operated mid-April through July for protection of sturgeon in all but 20 percent of the lowest observed April-September runoff volumes at Libby by supporting Bonners Ferry minimum flows. Sturgeon releases were not provided in operating years 1928-29, 1930-31, 1935-36, 1936-37, 1939-40, 1940-41, 1943-44, 1944-45, 1969-70, 1977-78, 1978-79, and 1987-88. Sturgeon flow objectives during April 16 through April 30 were to increase flows at Libby so that Bonners Ferry flow was at 424.8 $m^3/s$ (15,000 cfs) on May 1. From May 1 through 19, a minimum flow at Bonners Ferry of 424.8 $m^3/s$ (15,000 cfs) was maintained. From May 20 through June 30 augmentation from Libby tried to attempt to maintain a maximum flow at Bonners Ferry of 991.9 $m^3/s$ (35,000 cfs). From July 1 through July 21 a minimum flow at Bonners Ferry of 311.5 $m^3/s$ (11,000 cfs) was maintained. During July 22 through July 31 a minimum flow at Libby of 113.3 $m^3/s$ (4,000 cfs) was maintained. Libby's maximum outflow from mid-April through August is powerhouse hydraulic capacity without spill. Libby was not operated to support McNary flow objectives.

Hungry Horse was operated for power purpose to meet FELCC. The reservoir storage-elevation relationship reflected 3 percent bank storage. The project operation was regulated to support the Columbia Falls minimum flow of 99.1 $m^3/s$ (3,500 cfs) year round and maximum flow of 127.4 $m^3/s$ (4,500 cfs) October 15 through December 15. The maximum discharge from mid-April through August is powerhouse hydraulic capacity plus 85.0 $m^3/s$ (3,000 cfs) spill.

Grand Coulee was operated for power purpose to meet FELCC. At-site minimum flow is equal to 849.5 $m^3/s$ (30,000 cfs). The Vernita Bar minimum flows were supported by flow augmentation from Grand Coulee. The reservoir was operated to a drawdown limit of 0.4 m (1.3 ft) per day. A summer recreation minimum elevation of 391.7 m (1,285 ft) was observed in June and July. In May the pool was kept above elevation 378.0 m (1,240 ft) for pumping purposes into Banks Lake for irrigation.

Brownlee was operated to meet flood control, 566.3 $m^3/s$ (20,000 cfs) maximum flow in October and 254.9 $m^3/s$ (9,000 cfs) maximum flow in November. This operation is imposed over the 60-year fixed operation used in PNCA planning.

Dworshak was allowed to proportional draft to meet FELCC September 1 through May 31. For recreation during June through August, the reservoir was held above elevation 486.2 m (1,595 ft). In October, the maximum discharge was equal to inflow plus 36.8 $m^3/s$ (1,300 cfs).

Since John Day was operated at natural river it did not encroach on the tailwater at McNary. In this alternative McNary used the same stage vs. tailwater relationship as in Alternative B1 (see Section 4.8.3).

### 4.9.4 System Operations

The McNary and Lower Granite flow augmentation objectives were removed from this alternative and the Vernita Bar flow augmentation objectives were the same as Alternative A1. Upper Snake

flow augmentation was not adjusted to release 52.7 khm (427 KAF). The three remaining lower Columbia River projects continued to operate within 1 percent of peak efficiency and spill for juvenile bypassing remained the same as Alternative A1 at non-Federal projects, but changed at the Federal projects. Spill at Lower Granite, Little Goose, Lower Monumental, Ice Harbor, and John Day was removed. For the spill requirements at Bonneville, The Dalles, and McNary, see Section 4.2.4.7. A description of other system operations is found in Section 4.2.4.

## 4.10 Alternative C1

Alternative C1 is a continuous study of the system operations under a scenario where the Base Condition (Alternative A1) was adjusted for drawdown of the Lower Snake River Project to natural river levels and John Day was operated at spillway crest. It was assumed that non-Federal owners would remove their reservoirs from planning, thereby not requiring them to draft to meet load. Non-Federal projects were fixed on the operation resulting from the Base Condition regulation. Federal projects were allowed to pick up as much of the load lost from breaching the Lower Snake plants and operating John Day at spillway level as possible while still meeting project non-power requirements.

### 4.10.1 System Demand

The loads and secondary market used in this alternative were the same as Alternative A1 (see Section 4.2.1).

### 4.10.2 Rule Curves

Flood control rule curves in this alternative were the same as Alternative A1. Although John Day project was drawn down to spillway level, it was assumed that flood control space would remain, filling only to retain water during a flood event and evacuating as soon as practicable. The Variable Energy Content curves and Critical Rule Curves used in this alternative were the same as Alternative A1 (see Section 4.2.2).

### 4.10.3 Project Operations

Reservoirs were initialized to the same storage content used in Alternative A1, except at John Day, which was initialized to elevation 65.5 m (215 ft). Projects operated to the same non-power requirements used in Alternative A1. Other project operations used in this alternative remained unchanged from Alternative A1 (see Section 4.2.3).

When John Day project operates at spillway level there is no encroachment of the McNary tailwater by John Day pool. Therefore, a new stage vs. tailwater relationship, was used for the "C" series of alternatives (see Table 4-11).

### 4.10.4 System Operations

The McNary, Lower Granite, and Vernita Bar flow augmentation objectives used in this alternative were the same as Alternative A1. Upper Snake flow augmentation used in this alternative was the same as Alternative A1. The four lower Columbia projects continued to operate within 1 percent of peak efficiency. Spill for juvenile bypassing remained the same as Alternative A1 at non-Federal and at the Federal projects. Spill at Lower Granite, Little Goose, Lower Monumental, and Ice

Harbor was removed. For the spill requirements at Bonneville, The Dalles, John Day and McNary, see Section 4.2.4.7. A description of other system operations is found in Section 4.2.4.

### 4.10.5 BPA Operational Step

The operational step was performed the same as Alternative B1 (shown in Section 4.8.5) except that a John Day spill cap of 1,699.9 $m^3$.s (60,000 cfs) was used.

## 4.11 Alternative C2

This alternative is a continuous study of the system operations under a scenario where the Base Condition (Alternative A1) was adjusted only for drawdown of the Lower Snake River Project to natural river levels and John Day was operated at spillway crest. Flow augmentation on the Columbia River and Snake River are removed, thereby freeing up the reservoir operation for power purposes much of the time. Libby would still provide sturgeon releases. Juvenile bypass spill and 1 percent peak operation is retained. BPA did not model this alternative.

### 4.11.1 System Demand

The system demand or load for this alternative was developed from the operating year 1981-82 Critical Period study run by the NWPP as discussed in Section 4.9.1. The secondary market limit used in this alternative were the same as Alternative A1 (see Section 4.2.1).

### 4.11.2 Rule Curves

Flood control rule curves in this alternative were the same as Alternative A1, except that the system flood control at Dworshak and Brownlee was not shifted to Grand Coulee project since Snake River flow augmentation was removed. Although John Day project was drawn down to spillway level, it was assumed that flood control space would remain, filling only to retain water during a flood event and evacuating as soon as practicable.

The Variable Energy Content Curves used in this alternative were calculated using Operating Year 1979-80 PDRs and distribution factors and forecast errors which were used in PNCA planning. Canadian Treaty projects were calculated using AOP97 PDRs, the same as Alternative A1. At Grand Coulee the VECC was limited by the Gifford/Inchelium Ferry to elevation 371.9 m (1,220 ft). The volume forecast for all projects are based on actual runoff.

### 4.11.3 Project Operations

Storage reservoirs were initialized to the same elevations as Alternative A1 except Grand Coulee, Hungry Horse, Libby, Dworshak and John Day which were initialized to elevations 393.2 m (1,290 ft) (639.5 khm [2,614.4 ksfd]); 1,085.1 m (3,560 ft); 749.5 m (2,459 ft) [614.1 khm (2,510.5 ksfd)]; 487.7 m (1,600 ft) [248.5 khm (1,016.0 ksfd)]; and 65.5 m (215 ft), respectively. Projects operated to the same non-power requirements used in Alternative A1, except as noted below. See Section 4.2.3 for a description of other reservoirs.

Libby was operated in proportional draft during September through December to meet Decembers URC of elevation 734.9 m (2,411.0 ft) [367.4 khm (1,502.2 ksfd)]. In January through mid-April, Libby was operated on minimum flow or flood control. It should be noted that Libby does violate URC to allow Corra Linn's maximum lake level not to exceed the IJC 1938 Order. Libby was operated mid-April through July for protection of sturgeon in all but 20 percent of the worst

observed April-September runoff volumes at Libby by supporting Bonners Ferry minimum flows. Sturgeon releases were not provided in 1928-29, 1930-31, 1935-36, 1936-37, 1939-40, 1940-41, 1943-44, 1944-45, 1969-70, 1977-78, 1978-79, and 1987-88. Sturgeon flow objectives during April 16 through April 30 were to increase flows at Libby so that Bonners Ferry flow is at 424.8 khm (15,000 cfs) on May 1. From May 1 through May 19, a minimum flow at Bonners Ferry of 424.8 khm (15,000 cfs) was maintained. From May 20 through June 30 augmentation from Libby to maintain a maximum flow at Bonners Ferry of 991.1 $m^3/s$ (35,000 cfs). From July 1 through July 21 a minimum flow at Bonners Ferry of 311.5 $m^3/s$ (11,000 cfs) was maintained. During July 22 through July 31 a minimum flow at Libby of 113.3 $m^3/s$ (4,000 cfs) was maintained. Libby's maximum outflow from mid-April through August is powerhouse hydraulic capacity without spill. Libby was not operated to support McNary flow objectives.

Hungry Horse was operated for power purposes to meet FELCC. The reservoir storage-elevation relationship reflected 3 percent bank storage. The project operation was regulated to support the Columbia Falls minimum flow of 99.1 $m^3/s$ (3,500 cfs) year round and maximum flow of 127.4 $m^3/s$ (4,500 cfs) October 15 through December 15. The maximum discharge from mid-April through August is powerhouse hydraulic capacity plus 85.0 $m^3/s$ (3,000 cfs) spill.

Grand Coulee was operated for power purposes to meet FELCC. At-site minimum flow is equal to 849.5 $m^3/s$ (30,000 cfs). The Vernita Bar minimum flows were supported by flow augmentation from Grand Coulee. The reservoir observed a drawdown limit of 0.4 m (1.3 ft) per day. A summer recreation minimum elevation of 391.7 m (1,285 ft) was observed in June and July. In May the pool was kept above elevation 378.0 m (1,240 ft) for pumping purposes into Banks Lake for irrigation.

Brownlee was operated to meet flood control, 566.3 $m^3/s$ (20,000 cfs) maximum flow in October and 254.9 $m^3/s$ (9,000 cfs) maximum flow in November. This operation is imposed over the 60-year fixed operation used in PNCA planning.

Dworshak was allowed to draft to meet FELCC September 1 through May 31. For recreation during June through August, the reservoir was held above elevation 486.2 m (1,595 ft). In October, the maximum discharge is equal to inflow plus 36.8 $m^3/s$ (1,300 cfs).

Since John Day is operated at spillway level it did not encroach on the tailwater at McNary. This alternative used the same stage vs. tailwater relationship in Alternative B1 (see Section 4.8.3).

### 4.11.4 System Operations

The McNary and Lower Granite flow augmentation objectives were removed from this alternative and the Vernita Bar flow augmentation objectives were the same as Alternative A1. Upper Snake flow augmentation was not adjusted to release 52.7 khm (427 KAF). The four lower Columbia River projects continued to operate within 1 percent of peak efficiency and spill for juvenile bypassing remained the same as Alternative A1 at non-Federal projects, but changed at the Federal projects. Spill at Lower Granite, Little Goose, Lower Monumental, and Ice Harbor was removed. For the spill requirements at Bonneville, The Dalles, John Day, and McNary, see Section 4.2.4.7. A description of other system operations is found in Section 4.2.4.

# 5. Comparison of Results

## 5.1 Introduction

The results of computer simulations of the alternatives described in Chapter 4 are discussed in this chapter and compared against the Base Condition or no action Alternative A1. Three general categories of results were compared, system generation, reservoir elevations and flows.

Regulated hydroelectric projects in the northwest contribute to the system generation along with independent hydroelectric projects and thermal resources. Each alternative modeled provides different amounts of system generation depending on the non-power requirements assumed in each alternative investigated. At the end of this chapter is Table 5-1 which shows the 60-year average system generation for the regulated hydroelectric projects modeled in the PNW area. The table contains the average system generation by alternative for each period and the 60-year average annual system generation. Table 5-2 illustrates the difference in system generation compared to the Base Condition or Alternative A1. Also provided in Table 5-3 is the contribution of average generation from the four lower Snake River hydropower facilities—Lower Granite (LWG), Little Goose (LGS), Lower Monumental (LMN), and Ice Harbor (IHB). Values found in all three tables are in aMW.

Reservoirs draft and fill based on the PNW load, non-power requirements, and available stream flows. Table 5-4 illustrates the 60-year average reservoir elevations for each alternative investigated, by periods. The average annual reservoir elevation is also provided on the far right. Information is limited to the four major Federal storage projects, Libby (LIB), Hungry Horse (HGH), Grand Coulee (GCL), and Dworshak (DWR). In addition, the difference in average elevation compared the Base Condition is illustrated in Table 5-5 for each alternative. Values found in both tables are in feet.

As a result of the non-power requirements modeled, the 60 years of natural streamflows are regulated on the Columbia and Snake Rivers. Biological objectives are described in the Salmon Biological Opinion for Lower Granite and McNary. Table 5-6 and 5-7 show the 60-year average regulated flow for each alternative by period for Lower Granite and McNary, respectively. Also included in these two tables are the 60-year natural streamflows. The difference in regulated flows compared to the Base Condition is illustrated in Tables 5-8 and 5-9, respectively. Values found in all four tables are in cfs.

Displayed in Tables 5-10 and 5-11 are the number of years out of 60 that the Salmon Biological Opinion flow objectives were met at Lower Granite and McNary, respectively. The number of years met for the natural flow and the accomplishments of the regulated flow for each alternative are provided in these tables. There are no flow objectives in the Salmon Biological Opinion September through March.

Below is a discussion of the accomplishments of each alternative and a comparison of results from the Base Condition.

## 5.2 Alternative A1 Results

### 5.2.1 System Generation

The average annual system generation for regulated hydroelectric plants in the model was 14,038 aMW. The highest periods of system generation were in the last part of April, May, and June which coincide with the spring runoff and the spring flow augmentation period. In these periods the system generated

16,890 aMW, 18,729 aMW, and 18,834 aMW, respectively. During the peak load period in January the system generated 16,800 aMW. The periods of lowest system generation were in September at 9,466 aMW and October at 9,520 aMW.

### 5.2.2 Reservoir Elevations

The 60-year average annual reservoir elevations at Libby, Hungry Horse, Grand Coulee, and Dworshak were 732.9 m (2,404.5 ft); 1,073.9 m (3,523.4 ft); 386.9 m (1,269.5 ft); and 469.3 m (1,539.6 ft), respectively. Reservoirs drafted to their lowest point at the end of the flood control evacuation period in March or April to elevation 716.5 m (2,350.8 ft); 1,065.4 m (3,495.7 ft); 376.4 m (1,235.0 ft); and 460.7 m (1,511.5 ft), respectively. They achieved their highest point at the end of the flood control refill period in July to elevations 745.0 m (2,444.2 ft); 1,082.7 m (3,552.2 ft); and 392.2 m (1,286.9 ft), respectively, with the exception of Dworshak, which peaked in June at elevation 475.3 m (1,580.0 ft).

### 5.2.3 Flows

Flows from the Snake River are monitored at Lower Granite where flow objectives are identified in the Salmon Biological Opinion. The natural flow at Lower Granite increases from 586.2 $m^3$/s (20,701 cfs) in the last part of August to a peak of 3,440.0 $m^3$/s (121,483 cfs) in May and decreases back down to the lowest flow in the last part of August. In Alternative A1 the regulated flow increases from 672.6 $m^3$/s (23,751 cfs) in September to a peak of 3,114.4 $m^3$/s (109,972 cfs) in May and decreases back down to 672.6 $m^3$/s (23,751 cfs) in September with the exception of November where the regulated flow is the lowest at 555.0 $m^3$/s (19,598 cfs).

The Salmon Biological Opinion has identified flow objectives at McNary to control the Columbia River. At McNary, the natural flow increases from 2,349.1 $m^3$/s (82,959 cfs) in October to the peak flow of 13,123.8 $m^3$/s (463,462 cfs) in June with the exception of January which decreases slightly from the December streamflow. Natural flows decrease from the June peak down to the lowest flow in October. In Alternative A1, the regulated flow increased from 2,867.2 $m^3$/s (101,254 cfs) in September to a peak of 7,921.4 $m^3$/s (279,741 cfs) in June and decreased back down to the lowest flow in September, with the exception of January where the regulated flow was 5,376.6 $m^3$/s (189,872 cfs).

The Salmon Biological Opinion regulated flow objective at Lower Granite in Alternative A1 was met in 27 years during the last part of April, in 39 years during May, in 39 years during June, in 18 years in July, and in 4 years during the first part of August. Alternative A1 did not meet the objectives in any year during the last part of August. Using the natural flows compared to the Lower Granite flow objectives, they were met 24 years in the last part of April, 44 years in May, 44 years in June, 11 years in July, and no years in the first or last part of August.

At McNary, the Salmon Biological Opinion flow objectives were met in 40 years during the last part of April, in 57 years during May, in 28 years during June, in 5 years during July, in 1 year during the first part of August, and in no years during the last part of August. The natural flows met these objectives in 42 years during the last part of April, in 60 years during May, in 60 years during June, in 29 years during July, in 1 year during the first part of August, and in none during the last part of August.

## 5.3 Alternative A2 Impacts

### 5.3.1 System Generation

The average annual system generation for regulated hydroelectric plants in the model for Alternative A2 was 14,108 aMW. The highest period of system generation was in the last part of April, May, and June which coincide with the spring runoff and the spring flow augmentation period. In these periods the system generated 17,129 aMW; 19,049 aMW; and 19,139 aMW, respectively. During the peak load period in January the system generated 16,803 aMW. The periods of lowest system generation were in September at 9,467 aMW and October at 9,533 aMW.

In this alternative, spill for juvenile bypassing was eliminated at Lower Granite, Little Goose, Lower Monumental, and McNary. When compared with Alternative A1, the system generation was identical with the exception of the first part of April, the last part of April, May, and June when spill was eliminated. This allowed more water to be available for generation and increased the project annual generation by 10 to 20 aMW. The annual system generation increased by 71 aMW.

### 5.3.2 Reservoir Elevations

The 60-year average annual reservoir elevations at Libby, Hungry Horse, Grand Coulee and Dworshak were 732.9 m (2,404.4 ft); 1,073.9 m (3,523.3 ft); 386.9 m (1,269.5 ft); and 469.3 m (1,539.6 ft), respectively. Reservoirs drafted to their lowest point at the end the flood control evacuation period in March or April to elevation 716.5 m (2,350.7 ft); 1,065.4 m (3,495.5 ft); 376.4 m (1,235.0 ft); and 460.7 m (1,511.5 ft), respectively. They achieved their highest point at the end of the flood control refill period in July to elevations 744.9 m (2,444.0 ft); 1,082.7 m (3,552.2 ft); and 392.2 m (1,286.9 ft), with the exception of Dworshak, which peaked in June at elevation 475.3 m (1,580.0 ft). Reservoir elevations were almost identical when compared to Alternative A1. The maximum changes to the average reservoir elevations were 0.3 ft at Hungry Horse.

### 5.3.3 Flows

In Alternative A2 the regulated flow at Lower Granite increases from 672.6 $m^3/s$ (23,751 cfs) in September to a peak of 3,114.4 $m^3/s$ (109,975 cfs) in May and decreases back down to 672.6 $m^3/s$ (23,751 cfs) in September with the exception of November where the regulated flow is 554.6 $m^3/s$ (19,584 cfs). When compared to Alternative A1, the regulated flow at Lower Granite is almost identical showing a maximum difference of 0.7 $m^3/s$ (23 cfs) in any one period.

At McNary, in Alternative A2, the regulated flows increased from 2,865.2 $m^3/s$ (101,183 cfs) in September to a peak of 7,910.9 $m^3/s$ (279,372 cfs) in May and back down to the lowest flow in September with the exception of January where the regulated flow was 5,379.7 $m^3/s$ (189,984 cfs). The largest difference in regulated flow, when compared to Alternative A1, was in the last part of April, May, and June where the difference was between 8.5 $m^3/s$ (300 cfs) and 19.8 $m^3/s$ (700 cfs). Other periods varied less than 4.2 $m^3/s$ (150 cfs).

The Salmon Biological Opinion regulated flow objective at Lower Granite in Alternative A2 was met in 27 years during the last part of April, in 40 years during May, in 39 years during June, in 18 years in July, in 4 years during the first part of August, and in no years during the last part of August.

In Alternative A2 at McNary, the Salmon Biological Opinion flow objectives were met in 40 years during the last part of April, in 57 years during May, in 28 years during June, in 5 years during July, in 1 year during the first part of August, and in no years during the last part of August.

## 5.4 Alternative A3 Impacts

### 5.4.1 System Generation

The average annual system generation for regulated hydroelectric plants in the model for Alternative A3 was 12,771 aMW. The highest periods of system generation were in May and June which coincide with the spring runoff and the spring flow augmentation period. In these periods the system generated 16,314 aMW and 16,703 aMW, respectively. During the peak load period in January the system generated 15,987 aMW. The periods of lowest system generation were in September at 9,046 aMW and October at 8,953 aMW.

In this alternative, the Lower Snake River Project was drawn down to natural river level and generation from these plants was eliminated. Columbia River and Snake River flow augmentation remained unchanged. The reduction in system generation is mainly due to this effect. The annual generation from these plants in Alternative A1 is 1,246 aMW, ranging from 2,400 aMW in May to 500 aMW in November. There was some ability of the system to make up this lost generation at other plants.

### 5.4.2 Reservoir Elevations

The 60-year average annual reservoir elevations at Libby, Hungry Horse, Grand Coulee, and Dworshak were 732.6 m (2,403.5 ft); 1,073.5 m (3,522.0 ft); 386.2 m (1,267.2 ft); and 468.9 m (1,538.3 ft), respectively. Reservoirs drafted to their lowest point at the end of the flood control evacuation period in March or April to elevations 716.5 m (2,350.8 ft); 1,064.6 m (3,492.8 ft); 376.4 m (1,234.8 ft); and 460.6 m (1,511.1 ft), respectively. They achieved their highest point at the end of the flood control refill period in July to elevations 745.0 m (2,444.2 ft); 1,082.7 m (3,552.1 ft); 392.2 m (1,286.9 ft); and 475.9 m (1,561.0 ft), respectively.

When compared to Alternative A1, Libby drafted approximately 4 ft deeper September through November to help replace generation lost from the drawdown of the Lower Snake River Project. In other periods it was within 0.0 m (0.1 ft) of the elevations in Alternative A1. Hungry Horse drafted 0.3 m (0.9 ft) deeper September through December and approximately 0.9 m (3 ft) deeper January through April. The reservoir elevations May through August were 0.1 m (0.3 ft) deeper. The maximum changes to the average reservoir elevations in other periods were 0.1 m (0.3 ft). Grand Coulee drafted 0.3 m (0.9 ft) deeper September through December and approximately 0.9 m (3 ft) to 2.7 m (9 ft) deeper January through April. Dworshak drafted 0.6 m (2 ft) deeper July through December and 0.2 m (0.6 ft) deeper January through June. Deeper drafts are the result of projects attempting to replace generation lost due to drawdown of the four dams in the Lower Snake River Project.

### 5.4.3 Flows

In Alternative A3 the regulated flow at Lower Granite increases from 672.6 $m^3/s$ (23,751 cfs) in September to a peak of 3,114.8 $m^3/s$ (109,999 cfs) in May and decreases back down to 672.6 $m^3/s$ (23,751 cfs) in September with the exception of November where the regulated flow is 576.8 $m^3/s$ (20,371 cfs). When compared to Alternative A1, the regulated flow at Lower Granite is within the maximum differences of 21.9 $m^3/s$ (773 cfs); 40.6 $m^3/s$ (1,435 cfs); and 15.2 $m^3/s$ (537 cfs) in November,

the first part of April, and July, respectively. Other periods varied between 4.2 $m^3/s$ (150 cfs) and 8.5 $m^3/s$ (300 cfs).

At McNary, in Alternative A3, the regulated flows increased from 2,916.8 $m^3/s$ (103,006 cfs) in September to a peak of 7,900.5 $m^3/s$ (279,002 cfs) in May and back down to the lowest flow in September, with the exception of January and March where the regulated flow was 5,495.2 $m^3/s$ (194,060 cfs) and 4,467.4 $m^3/s$ (157,766 cfs), respectively. When compared to Alternative A1, the regulated flows increased from the last part of August to November between 42.5 $m^3/s$ (1,500 cfs) and 99.1 $m^3/s$ (3,500 cfs). December had a 70.8 $m^3/s$ 2,500 cfs) decrease in regulated flow. From March through May the regulated flows increased from 19.8 $m^3/s$ (700 cfs) to 254.9 $m^3/s$ (9,000 cfs).

The Salmon Biological Opinion regulated flow objective at Lower Granite in Alternative A3 was met in 27 years during the last part of April, in 41 years during May, in 41 years during June, in 21 years in July, in 4 years during the first part of August, and in no years during the last part of August.

In Alternative A3 at McNary, the Salmon Biological Opinion flow objectives were met in 40 years during the last part of April, in 57 years during May, in 35 years during June, in 5 years during July, in 1 year during the first part of August, and in no years during the last part of August.

## 5.5 Alternative A5 Impacts

### 5.5.1 System Generation

The average annual system generation for regulated hydroelectric plants in the model for Alternative A5 was 12,805 aMW. The highest periods of system generation were in May and June which coincide with the spring runoff and the spring augmentation period. In these periods the system generated 16,078 aMW and 16,538 aMW, respectively. During the peak load period in January the system generated 16,230 aMW which was as high as the May and June periods. The periods of lowest system generation were in the last part of August at 9,699 aMW, September at 9,317 aMW, and October at 9,107 aMW.

In this alternative, the Lower Snake River Project was drawn down to natural river level, and generation from these plants was eliminated. In addition, the Snake River flow augmentation was removed. The reduction in system generation is mainly due to these projects being drawn down to natural river level. The annual generation from these plants in Alternative A1 is 1,246 aMW, ranging from 2,400 aMW in May to 500 aMW in November. Eliminating the Snake River flow augmentation allowed regulation of Dworshak storage for power, decreasing the May and June system generation and increasing the December, January, and February system generation. Elimination of the Snake River flow augmentation allowed the system to gain 34 aMW of annual generation, the difference between A3 and A5. There was some ability of the system to make up this lost generation at other plants.

### 5.5.2 Reservoir Elevations

The 60-year average annual reservoir elevations at Libby, Hungry Horse, Grand Coulee, and Dworshak were 732.7 m (2,403.8 ft); 1,073.6 m (3,522.3 ft); 386.3 m (1,267.5 ft); and 466.0 m (1,528.9 ft), respectively. Reservoirs drafted to their lowest point at the end the flood control evacuation period in March or April to elevations 716.5 m (2,350.8 ft); 1,064.8 m (3,493.4 ft); 376.3 m (1,234.5 ft); and 445.5 m (1,461.6 ft), respectively. They achieved their highest point at the end of the flood control refill period in July to elevations 745.0 m (2,444.1 ft); 1,082.6 m (3,551.7 ft); 392.2 m (1,286.7 ft); and 485.3 m (1,592.3 ft), respectively.

When compared to Alternative A1, Libby drafted approximately 0.9 m (3 ft) deeper September through November to help replace generation lost from the drawdown of the Lower Snake River Project. In other periods it was within 0.0 m (0.1 ft) of the elevations in Alternative A1. Hungry Horse drafted 0.1 m (0.3 ft) deeper September through December and approximately 0.9 m (3 ft) deeper January through April. The reservoir elevations May through August were 0.2 m (0.5 ft) deeper. The maximum changes to the average reservoir elevations in other periods were 0.1 m (0.3 ft). Grand Coulee drafted 0.1 m (0.4 ft) deeper September through December and approximately 0.6 m (2 ft) to 2.4 m (8 ft) deeper January through April. Dworshak had significant reservoir elevation differences compared to Alternative A1 due to the removal of Snake River flow augmentation. From November through May the project drafted between 6.1 m (20 ft) and 17.7 m (58 ft) deeper. From June through October the reservoir was 3.0 m (10 ft) to 17.7 m (58ft) higher. The average annual reservoir elevation at Dworshak was lowered by 3.3 m (10.7 ft). Deeper drafts are the result of projects attempting to replace generation lost due to drawdown.

### 5.5.3 Flows

In Alternative A5, the regulated flow at Lower Granite increases from 600.2 $m^3/s$ (21,196 cfs) in the last part of August to a peak of 2,953.9 $m^3/s$ (104,316 cfs) in May and decreases back down to the lowest point in the last part of August with the exception of September, when the regulated flow is 981.6 $m^3/s$ (34,666 cfs). When compared to Alternative A1, the regulated flow at Lower Granite increased in September through February from 566.0 $m^3/s$ (2,000 cfs) to 311.5 $m^3/s$ (11,000 cfs) and decreased in March through August from 14.2 $m^3/s$ (500 cfs) to 339.8 $m^3/s$ (12,000 cfs).

At McNary, in Alternative A5, the regulated flows increased from 3,073.1 $m^3/s$ (108,527 cfs) in October to a peak of 7,760.4 $m^3/s$ (274,055 cfs) in May and back down to the lowest flow in October with the exception of January and March where the regulated flow was 5,598.8 $m^3/s$ (197,718 cfs) and 4,464.1 $m^3/s$ (157,649 cfs), respectively. When compared to Alternative A1, the regulated flows increased from September to February between 113.3 $m^3/s$ (4,000 cfs) and 311.5 $m^3/s$ (11,000 cfs) and decreased from March to August between 85.0 $m^3/s$ (3,000 cfs) and 453.1 $m^3/s$ (16,000 cfs).

The Salmon Biological Opinion regulated flow objective at Lower Granite in Alternative A5 was met in 19 years during the last part of April, in 34 years during May, in 39 years during June, in 11 years in July, and in no years during the first or last part of August.

In Alternative A5 at McNary, the Salmon Biological Opinion flow objectives were met in 37 years during the last part of April, in 54 years during May, in 29 years during June, in 4 years during July, in 1 year during the first part of August, and in no years during the last part of August.

## 5.6 Alternative A6a Impacts

### 5.6.1 System Generation

The average annual system generation for regulated hydroelectric plants in the model for Alternative A6a was 14,064 aMW. The highest periods of system generation were in the last part of April, May, and June, which coincide with the spring runoff and the spring flow augmentation period. In these periods the system generated 17,221 aMW; 18,544 aMW; and 18,879 aMW, respectively. During the peak load period in January the system generated 16,860 aMW. The periods of lowest system generation were in September at 9,495 aMW and October at 9,535 aMW.

This alternative was adjusted to reflect an additional 123.3 khm (1.0 MAF) of upper Snake storage for flow augmentation, a total of 176.0 khm (1,427 KAF). When compared with Alternative A1, this allowed more water from the upper Snake River Basin to be available for flow augmentation during the spring and summer when Lower Snake and Columbia River projects are spilling water to bypass juveniles downstream. System generation decreased during this period because more flow was subject to spill. This decreases the average annual system generation by 26 aMW.

### 5.6.2 Reservoir Elevations

The 60-year average annual reservoir elevations at Libby, Hungry Horse, Grand Coulee, and Dworshak were 723.8 m (2,404.3 ft); 1,073.7 m (3,522.7 ft); 386.8 m (1,269.1 ft); and 469.1 m (1,539.2 ft), respectively. Reservoirs drafted to their lowest point at the end the flood control evacuation period in March or April to elevations 716.5 m (2,350.8 ft); 1,065.2 m (3,494.8 ft; 375.6 m (1,232.2 ft); and 460.4 m (1,510.5 ft). They achieved their highest point at the end of the flood control refill period in July to elevations 745.0 m (2,444.2 ft); 1,082.5 m (3,551.5 ft); and 392.1 m (1,286.5 ft), with the exception of Dworshak, which peaked in June at elevation 485.0 m (1,591.3 ft).

When compared to Alternative A1, Libby, Hungry Horse, and Grand Coulee drafted less than 0.3 m (1.0 ft) deeper through the operating year. Dworshak drafted less than 1.2 m (4.0 ft) deeper from August through December. From April through June the reservoir was 0.9 m (3.0 ft) to 4.9 m (16 ft) higher. Deeper drafts are the result of projects attempting to replace generation lost due to drawdown.

### 5.6.3 Flows

In Alternative A6a the regulated flow at Lower Granite increases from 642.2 $m^3/s$ (22,679 cfs) in September to a peak of 3,133.6 $m^3/s$ (110,663 cfs) in May and decreases back down to the lowest point in September, with the exception of November where the regulated flow is 535.9 $m^3/s$ (18,925 cfs). When compared to Alternative A1, the regulated flow at Lower Granite decreased in October through the first part of April from 5.7 $m^3/s$ (200 cfs) to 48.1 $m^3/s$ (1,700 cfs) and increased in the last part of April through September from 14.2 $m^3/s$ (500 cfs) to 2.8 $m^3/s$ (7,700 cfs).

At McNary, in Alternative A6a, the regulated flows increased from 2,844.7 $m^3/s$ (100,459 cfs) in September to a peak of 7,866.6, $m^3/s$ (277,808 cfs) in May and back down to the lowest flow in September, with the exception of February and March where the regulated flow was 4,820 $m^3/s$ (170,218 cfs) and 4,628.3 $m^3/s$ (163,448 cfs), respectively. When compared to Alternative A1, the regulated flow decreased 54.7 $m^3/s$ (1,933 cfs) in May and 26.5 $m^3/s$ (936 cfs) in February. The regulated flows increased 113.1 $m^3/s$ (3,994 cfs) in the first part of August; 243.7 $m^3/s$ (8,607 cfs) in the last part of August; 140.5 $m^3/s$ (4,963 cfs) in the last part of April; 84.2 $m^3/s$ (2,975 cfs) in June; and 59.3 $m^3/s$ (2,095 cfs) in July. In other periods the change in flow was less than 22.7 $m^3/s$ (800 cfs).

The Salmon Biological Opinion regulated flow objective at Lower Granite in Alternative A6a was met in 29 years during the last part of April, in 43 years during May, in 46 years during June, in 19 years in July, in 6 years during the first part of August, and in 2 years during the last part of August.

In Alternative A6a at McNary, the Salmon Biological Opinion flow objectives were met in 47 years during the last part of April, in 54 years during May, in 39 years during June, in 5 years during July, in 1 year during the first part of August, and in no years during the last part of August.

# 5.7 Alternative A6b Impacts

## 5.7.1 System Generation

The average annual system generation for regulated hydroelectric plants in the model for Alternative A6b was 14,028 aMW. The highest periods of system generation were in the last part of April, May, and June, which coincide with the spring runoff and the spring augmentation period. In these periods the system generated 17,346 aMW; 18,578 aMW; and 18,756 aMW, respectively. During the peak load period in January the system generated 16,840 aMW. The periods of lowest system generation were in September at 9,412 aMW and October at 9,504 aMW.

This alternative was not adjusted to reflect upper Snake storage for flow augmentation. When compared to Alternative A1, this allowed less water from the upper Snake River Basin to be available for flow augmentation during the spring and summer. This slightly decreased the average annual system generation by 10 aMW.

## 5.7.2 Reservoir Elevations

The 60-year average annual reservoir elevations at Libby, Hungry Horse, Grand Coulee, and Dworshak were 732.8 m (2,404.3 ft); 1,073.7 m (3,522.6 ft); 386.9 m (1,269.2 ft); and 466.3 m (1,530.0 ft), respectively. Reservoirs drafted to their lowest point at the end the flood control evacuation period in March or April to elevations 716.5 m (2,350.8 ft); 1,065.1 m (3,494.5 ft); 375.6 m (1,232.2 ft); and 458.8 m (1,505.3 ft). They achieved their highest point at the end of the flood control refill period in July to elevations 745.0 m (2,444.2 ft); 1,082.5 m (3,551.4 ft); and 392.2 m (1,286.9 ft), with the exception of Dworshak, which peaked in June at elevation 480.5 m (1,576.6 ft).

When compared to Alternative A1, Libby drafted less than 0.3 m (1.0 ft) deeper and showed no change from December through July. Hungry Horse drafted less than 0.3 m (1.0 ft) deeper in all periods. Grand Coulee drafted less than 0.3 m (1.0 ft) deeper in all periods with the exception of April, when it drafted 0.9 m (2.8 ft) deeper. Dworshak drafted between 3.0 m (10 ft) and 4.6 m (15 ft) deeper from August through January. From February through July the reservoir drafted between 1.2 m (4.0 ft) and 2.4 m (8.0 ft) deeper. The average annual reservoir elevation at Dworshak was 3.0 m (9.8 ft) deeper. Deeper drafts are the result of other projects attempting to replace generation lost due to drawdown.

## 5.7.3 Flows

In Alternative A6b the regulated flow at Lower Granite increases from 654.3 $m^3/s$ (23,105 cfs) in September to a peak of 3,119.4 $m^3/s$ (110,161 cfs) in May and decreases back down to 654.3 $m^3/s$ (23,105 cfs) in September, with the exception of November where the regulated flow is 583.6 $m^3/s$ (20,611 cfs). When compared to Alternative A1, the regulated flow at Lower Granite increased 29.1 $m^3/s$ (1,029 cfs) in the first part of August; 28.7 $m^3/s$ (1,013 cfs) in November; and 27.6 $m^3/s$ (974 cfs) in December. The regulated flows decreased 78.1 $m^3/s$ (2,534 cfs) in the last part of August and 43.8 $m^3/s$ (1,547 cfs) in July. Other periods changed less than 18.4 $m^3/s$ (650 cfs).

At McNary, in Alternative A6b, the regulated flows increased from 2,836.7 $m^3/s$ (100,177 cfs) in September to a peak of 7,861.1 $m^3/s$ (277,613 cfs) in May and back down to the lowest flow in September with the exception of January and March where the regulated flow was 5,404.9 $m^3/s$ (190,871 cfs) and 4,647.7 $m^3/s$ (164,132 cfs), respectively. When compared to Alternative A1, the regulated flows increased 27.6 $m^3/s$ (973 cfs) in November; 28.3 $m^3/s$ (999 cfs) in January; and 200.7 $m^3/s$ (7,088 cfs) in the last part of April. The regulated flows decreased 41.4 $m^3/s$ (1,461 cfs) in the last part of August;

30.5 $m^3/s$ (1,077 cfs) in September; 33.0 $m^3/s$ (1,166 cfs) in February; 60.3 $m^3/s$ (2,128 cfs) in May; and 29.3 $m^3/s$ (1,036 cfs) in July. Other periods changed less than 21.2 $m^3/s$ (750 cfs).

The Salmon Biological Opinion regulated flow objective at Lower Granite in Alternative A6b was met in 28 years during the last part of April, in 39 years during May, in 40 years during June, in 13 years in July, in 3 years during the first part of August, and in no years during the last part of August.

In Alternative A6b at McNary, the Salmon Biological Opinion flow objectives were met in 47 years during the last part of April, in 54 years during May, in 31 years during June, in 5 years during July, in 1 year during the first part of August, and in no years during the last part of August.

## 5.8 Alternative B1 Impacts

### 5.8.1 System Generation

The average annual system generation for regulated hydroelectric plants in the model for Alternative B1 was 11,647 aMW as shown in Table 5-1. The highest periods of system generation were in May and June which coincide with the spring runoff and the spring flow augmentation period. In these periods the system generated 14,693 aMW and 15,114 aMW, respectively. During the peak load period in January the system generated 14,535 aMW. The periods of lowest system generation were in the last part of August at 9,835 aMW; September at 8,703 aMW; October at 8,519 aMW; and November at 9,377 aMW.

In this alternative the Lower Snake River Project and John Day were drawn down to natural river level causing generation from these plants to be eliminated. Columbia River and Snake River flow augmentation remained unchanged. The reduction in system generation is mainly due to these projects being drawn down to natural river level. The annual generation from these plants in Alternative A1 is 2,416 aMW, ranging from 4,102 aMW in May to 1,270 aMW in the last part of August. McNary project was able to increase its average annual generation without the John Day project tailwater encroachment by 72 aMW. The net change in system generation, including McNary project was a loss of 2,344 aMW. There was some ability of the system to make up this lost generation at other plants.

### 5.8.2 Reservoir Elevations

The 60-year average annual reservoir elevations at Libby, Hungry Horse, Grand Coulee, and Dworshak were 732.3 m (2,402.5 ft); 1,073.2 m (3,521.1 ft); 385.7 m (1,265.5 ft); and 468.9 m (1,538.4 ft), respectively. Reservoirs drafted to their lowest point at the end the flood control evacuation period in March or April to elevations 716.6 m (2,351.0 ft); 1,064.4 m (3,492.2 ft); 377.7 m (1,234.7 ft); and 460.6 m (1,511.1 ft). They achieved their highest point at the end of the flood control refill period in July to elevations 745.0 m (2,444.2 ft); 1,082.6 m (3,551.8 ft); and 392.2 m (1,286.9 ft); with the exception of Dworshak, which peaked in June at elevation 481.6 m (1,579.9 ft).

When compared to Alternative A1, Libby drafted approximately 2.4 m (8 ft) deeper September through November to help replace generation lost from the drawdown of the Lower Snake River Project. Other periods were within 0.2 m (0.5 ft) of the elevations in Alternative A1. Hungry Horse drafted 0.5 m (1.5 ft) deeper September through December and from 0.3 m (1.0 ft) to 2.6 m (8.4 ft) deeper January through April. The reservoir elevations May through August drafted 0.1 m (0.3 ft) deeper. Grand Coulee, from September through April drafted approximately 0.3 m (1 ft) to 4.0 m (13 ft) deeper and varied less than 0.3 m (1.0 ft) during the other periods. Dworshak drafted 0.6 m (2 ft) deeper July through December and varied less than 0.3 m (1.0 ft) deeper the rest of the year. Deeper drafts are the result of projects attempting to replace generation lost due to drawdown.

### 5.8.3 Flows

In Alternative B1 the regulated flow at Lower Granite increases from 672.6 $m^3/s$ (23,751 cfs) in September to a peak of 3,107 $m^3/s$ (109,721 cfs) in May and decreases back down to 672.6 $m^3/s$ (23,751 cfs) in September, with the exception of November where the regulated flow is 578.4 $m^3/s$ (20,425 cfs). When compared to Alternative A1, the regulated flow at Lower Granite increased 23.4 $m^3/s$ (827 cfs) in November and 15.3 $m^3/s$ (539 cfs) in July. The regulated flows decreased 40.6 $m^3/s$ (1,435 cfs) in the first part of April. Other periods changed less than 9.9 $m^3/s$ (350 cfs).

At McNary, in Alternative B1, the regulated flows increased from 3,024.2 $m^3/s$ (106,797 cfs) in September to a peak of 7,895.3 $m^3/s$ (278,820) cfs in May and back down to the lowest flow in September, with the exception of January and March where the regulated flow was 5,528.2 $m^3/s$ (195,228 ft) and 4,350.5 $m^3/s$ (153,637 cfs), respectively. When compared to Alternative A1, the regulated flows increased 97.5 $m^3/s$ (3,442 cfs) in the last part of August; 157.0 $m^3/s$ (5,543 cfs) in September; 136.3 $m^3/s$ (4,813 cfs) in October; 155.1 $m^3/s$ (5,478 cfs) in November; 151.7 $m^3/s$ (5,356 cfs) in January; 24.0 $m^3/s$ (849 cfs) in June; and 45.8 $m^3/s$ (1,616 cfs) in July. The regulated flows decreased 137.4 $m^3/s$ (4,851 cfs) in December; 38.4 $m^3/s$ (1,357 cfs) in February; 293.8 $m^3/s$ (10,376 cfs) in March; 271.6 $m^3/s$ (9,590 cfs) in the first part of April; 150.2 $m^3/s$ (5,303 cfs) in the last part of April; and 26.1 $m^3/s$ 921 cfs in May. Other periods changed less than 2.8 $m^3/s$ (100 cfs).

The Salmon Biological Opinion regulated flow objective at Lower Granite in Alternative B1 was met in 27 years during the last part of April, in 41 years during May, in 39 years during June, in 23 years in July, in 4 years during the first part of August, and in no years during the last part of August.

In Alternative B1 at McNary, the Salmon Biological Opinion flow objectives were met in 40 years during the last part of April, in 57 years during May, in 34 years during June, in 5 years during July, in 1 year during the first part of August, and in no years during the last part of August.

## 5.9 Alternative B2 Impacts

### 5.9.1 System Generation

The average annual system generation for regulated hydroelectric plants in the model for Alternative B2 was 11,734 aMW. The highest period of system generation was during the peak load in January when the system generated 15,902 aMW. The periods of lowest system generation were in the first part of August at 9,621 aMW; the last part of August at 8,880 aMW; September at 8,062 aMW; and October at 8,706 aMW.

In this alternative, the Lower Snake River Project and John Day were drawn down to natural river level causing generation from these plants to be eliminated. Columbia River and Snake River flow augmentation was removed. The reduction in system generation is mainly due to these projects being drawn down to natural river. The McNary project was able to increase its average annual generation without the John Day project tailwater encroachment by 72 aMW. The net change in system generation, including McNary project was a loss of 2,344 aMW. Eliminating the Columbia River and Snake River flow augmentation allowed regulation of storage projects for power allowing the system to gain 87 aMW of annual generation, the difference between B1 and B2. There was some ability of the system to make up this lost generation at other plants.

### 5.9.2 Reservoir Elevations

The 60-year average annual reservoir elevations at Libby, Hungry Horse, Grand Coulee, and Dworshak were 734.0 m (2,408.3 ft); 1,075.2 m (3,527.6 ft); 386.2 m (1,267.1 ft); and 470.6 m (1,544.1 ft), respectively. Reservoirs drafted to their lowest point at the end of the flood control evacuation period in March or April to elevations 716.5 m (2,350.7 ft); 1,063.1 m (3,487.8 ft); 373.4 m (1,225.1 ft); and 449.4 m (1,474.3 ft). They achieved their highest point at the end of the flood control refill period in July to elevations 1,082.6 m (3,557.3 ft); 392.2 m (1,290.0 ft); and 485.3 m (1,598.5 ft) except for Libby which peaked in September to elevation 746.5 m (2,449.3 ft).

When compared to Alternative A1, Libby operated approximately 1.5 m (5.0 ft) to 6.1 m (20 ft) higher August through October. Other periods were within 0.5 m (1.5 ft) of the elevations in Alternative A1. Hungry Horse operated 1.4 m (4.5 ft) to 4.1 m (13.5 ft) higher June through December and approximately 0.9 m (3.0 ft) to 2.4 m (8.0 ft) deeper February through May. Grand Coulee operated 0.9 m (3.0 ft) to 2.1 m (7.0 ft) higher June through December and drafted approximately 0.9 m (3.0 ft) to 5.8 m (19 ft) deeper January through May. Dworshak had significant reservoir elevation differences compared to Alternative A1 due to the removal of Snake River flow augmentation. From December through April the project drafted between 4.3 m (14 ft) and 12.2 m (40 ft) deeper. From May through November the reservoir was 0.9 m (3.0 ft) to 18.9 m (62 ft) higher. The average annual reservoir elevation at Dworshak lowered by 1.4 m (4.5 ft). Deeper drafts are the result of other projects attempting to replace generation lost due to drawdown.

### 5.9.3 Flows

In Alternative B2 the regulated flow at Lower Granite increases from 747.6 $m^3/s$ (26,403 cfs) in November to a peak of 2,972.6 $m^3/s$ (104,978 cfs) in May and decreases back down to the lowest point of 609.7 $m^3/s$ (21,530 cfs) in August, with the exception of September and October where the regulated flow is 877.7 $m^3/s$ (30,995 cfs) and 822.4 $m^3/s$ (29,043 cfs), respectively. When compared to Alternative A1, the regulated flow at Lower Granite increased between 89.7 $m^3/s$ (3,167 cfs) and 216.5 $m^3/s$ (7,646 cfs) from September to February. The regulated flows decreased between 32.3 $m^3/s$ (1,142 cfs) and 467.8 $m^3/s$ (16,521 cfs) from the first part of April to August. Other periods changed less than 4.2 $m^3/s$ (150 cfs).

At McNary, in Alternative B2, the regulated flows increased from 2,978.5 $m^3/s$ (105,184 cfs) in September to a peak of 7,723.6 $m^3/s$ (272,758 cfs) in May and back down to the lowest flow in September, with the exception of January and February where the regulated flow was 5,935.9 $m^3/s$ (209,626 cfs) and 5,482.5 $m^3/s$ (193,612 cfs), respectively. When compared to Alternative A1, the regulated flows increased between 81.8 $m^3/s$ (2,887 cfs) and 635.9 $m^3/s$ (22,458 cfs) from September to March. The regulated flows decreased between 197.7 $m^3/s$ (6,983 cfs) and 940.9 $m^3/s$ (33,227 cfs) from the first part of April to the last part of August.

The Salmon Biological Opinion regulated flow objective at Lower Granite in Alternative B2 was met in 20 years during the last part of April, in 35 years during May, in 38 years during June, in 11 years in July, and in no years during the first or last part of August.

In Alternative B2 at McNary, the Salmon Biological Opinion flow objectives were met in 33 years during the last part of April, in 50 years during May, in 25 years during June, in 4 years during July, in 1 year during the first part of August, and in no years during the last part of August.

# 5.10 Alternative C1 Impacts

## 5.10.1 System Generation

The average annual system generation for regulated hydroelectric plants in the model for Alternative C1 was 12,206 aMW as shown in Table 5-1. The highest periods of system generation were in May and June which coincide with the spring runoff and the spring flow augmentation period. In these periods the system generated 15,430 aMW and 15,820 aMW, respectively. During the peak load period in January the system generated 15,311 aMW, which was nearly as high as the May and June generation. The periods of lowest system generation were in September at 8,866 aMW; October at 8,764 aMW; and November at 9,767 aMW.

In this alternative, the Lower Snake River Project was drawn down to natural river level, and John Day was operated at spillway level. Generation from the Snake River plants was eliminated and the generation at John Day was reduced substantially. The reduction in system generation is mainly due to the Snake River Project being drawn down to natural river level and John Day being operated at spillway level. John Day was able to generate when operated at spillway, but at a reduced level. The net generation lost when compared to Alternative A1 is 625 average annual MW, ranging from 969 aMW in May to 322 aMW in the last part of August. McNary project was able to increase its average annual generation without the John Day project tailwater encroachment by 72 aMW. The net change in system generation, including the McNary project, was a loss of 1,799 aMW. There was some ability of the system to make up this lost generation at other plants. Columbia River and Snake River flow augmentation remained unchanged.

## 5.10.2 Reservoir Elevations

The 60-year average annual reservoir elevations at Libby, Hungry Horse, Grand Coulee, and Dworshak were 732.5 m (2,403.1 ft); 1,073.3 m (3,521.4 ft); 385.9 m (1,266.2 ft); and 468.9 m (1,538.3 ft), respectively. Reservoirs drafted to their lowest point at the end of the flood control evacuation period in March or April to elevations 716.5 m (2,350.8 ft); 1,064.5 m (3,492.3 ft); 376.3 (1,234.7 ft); and 460.6 m (1,511.1 ft). They achieved their highest point at the end of the flood control refill period in July to elevations 745 m (2,444.2 ft), 1,082.6 m (3,551.8 ft), and 392.2 m (1,286.9 ft), with the exception of Dworshak, which peaked in June at elevation 481.5 m (1,579.8 ft).

When compared to Alternative A1, Libby drafted approximately 1.8 m (6.0 ft) deeper September through November to help replace generation lost from the drawdown of the Lower Snake River Project. Other periods were within 0.2 m (0.5 ft) of the elevations in Alternative A1. Hungry Horse drafted 0.5 m (1.5 ft) deeper September through December and from 0.3 m (1.0 ft) to 1.9 m (6.2 ft) deeper January through April. The reservoir elevations May through August were 0.2 m (0.5 ft) deeper. Grand Coulee, from October through April, drafted approximately 0.65 m (2.0 ft) to 3.7 m (12 ft) deeper and varied less than 0.3 m (1.0 foot) during the other periods. Dworshak drafted 0.6 m (2 ft) deeper July through December and varied less than 0.3 m (1.0 foot) deeper the rest of the year. Deeper drafts are the result of other projects attempting to replace generation lost due to drawdown.

## 5.10.3 Flows

In Alternative C1 the regulated flow at Lower Granite increases from 672.6 $m^3/s$ (23,751 cfs) in September to a peak of 3,093.3 $m^3/s$ (109,240 cfs) in May and decreases back down to 672.6 $m^3/s$ (23,751 cfs) in September, with the exception of November when the regulated flow is 578.2 $m^3/s$ (20,419

cfs). When compared to Alternative A1, the regulated flow at Lower Granite increased 23.2 $m^3/s$ (821 cfs) in November, 22.1 $m^3/s$ (779 cfs) in June, and 14.4 $m^3/s$ (509 cfs) in July. The regulated flows decreased 40.6 $m^3/s$ (1,435 cfs) in the first part of April and 20.7 $m^3/s$ (732) in May. Other periods changed less than 9.9 $m^3/s$ (350 cfs).

At McNary, in Alternative C1, the regulated flows increased from 2,962.1 $m^3/s$ (104,606 cfs) in September to a peak of 7,884.4 $m^3/s$ (278,435 cfs) in May and back down to the lowest flow in September, with the exception of January and February when the regulated flow was 5,533 $m^3/s$ (195,397 cfs) and 4,872.3 $m^3/s$ (172,063 cfs), respectively. When compared to Alternative A1, the regulated flows increased 94.2 $m^3/s$ (3,327 cfs) in the last part of August; 94.9 $m^3/s$ (3,352 cfs) in September; 80.3 $m^3/s$ (2,836 cfs) in October; 137 $m^3/s$ (4,838 cfs) in November; 156.5 $m^3/s$ (5,525 cfs) in January; 25.7 $m^3/s$ (909 cfs) in February; 34.5 $m^3/s$ (1,218 cfs) in June; and 46.8 $m^3/s$ (1,652 cfs) in July. The regulated flows decreased 107.6 $m^3/s$ (3,801 cfs) in December; 250.5 $m^3/s$ (8,845 cfs) in March; 275.6 $m^3/s$ (9,734 cfs) in the first part of April; 145.9 $m^3/s$ (5,151) in the last part of April; and 37 $m^3/s$ (1,306 cfs) in May. Other periods changed less than 5.7 $m^3/s$ (200 cfs).

The Salmon Biological Opinion regulated flow objective at Lower Granite in Alternative C1 was met in 27 years during the last part of April, in 40 years during May, in 41 years during June, in 22 years in July, in 4 years during the first part of August, and in no years during the last part of August.

In Alternative B1 at McNary, the Salmon Biological Opinion flow objectives were met in 40 years during the last part of April, in 57 years during May, in 33 years during June, in 5 years during July, in 1 year during the first part of August, and in no years during the last part of August.

## 5.11 Alternative C2 Impacts

### 5.11.1 System Generation

The average annual system generation for regulated hydroelectric plants in the model for Alternative B2 was 12,276 aMW as shown in Table 5-1. The highest period of system generation was during January and February when the system generated 16,506 aMW and 14,992 aMW. The periods of lowest system generation were in the last part of August at 9,348 aMW; September at 8,384 aMW; and October at 9,085 aMW.

In this alternative, the Lower Snake River Project was drawn down to natural river level, causing generation from these hydropower facilities to be eliminated, and John Day was operated at spillway level, causing its generation to be reduced. Columbia River and Snake River flow augmentation was removed. The reduction in system generation is mainly due to these projects being drawn down. John Day was able to generate when operated at spillway, but at a reduced level. The net generation lost when compared to Alternative A1 is 619 average annual MW, ranging from 1,000 aMW in May to 364 aMW in the last part of August. McNary project was able to increase its average annual generation without the John Day project tailwater encroachment by 73 aMW. The net change in system generation, including McNary project was a loss of 1,792 aMW. Eliminating the Columbia River and Snake River flow augmentation allowed regulation of storage projects for power allowing the system to gain 70 aMW of annual generation, the difference between C1 and C2. There was some ability of the system to make up this lost generation at other plants.

### 5.11.2 Reservoir Elevations

The 60-year average annual reservoir elevations at Libby, Hungry Horse, Grand Coulee, and Dworshak were 734 m (2,408.0 ft); 1074.8 m (3,526.3 ft); 385.7 m (1,265.3 ft); and 470.6 m (1,544.1 ft), respectively. Reservoirs drafted to their lowest point at the end the flood control evacuation period in March or April to elevations 716.5 m (2,350.8 ft); 1063 m (3,487.4 ft); 370.9 m (1,216.8 ft); and 449.3 m (1,474.2 ft). They achieved their highest point at the end of the flood control refill period in July to elevation 1083.8 m (3,555.8 ft); 393.2 m (1,290.0 ft); and 487.2 m (1,598.4 ft) except at Libby, which peaked in September to elevation 746.1 m (2,447.9 ft).

When compared to Alternative A1, Libby operated approximately 1.5 m (5.0 ft) to 5.5 m (18 ft) higher August through October. Other periods were within 0.5 m (1.5 ft) of the elevations in Alternative A1. Hungry Horse operated 0.7 m (2.2 ft) to 3.6 m (11.7 ft) higher June through January and approximately 1.3 m (4.4 ft) to 2.4 m (8.0 ft) deeper February through May. Grand Coulee operated 0.9 m (3.0 ft) to 2.1 m (7.0 ft) higher June through December and drafted approximately 0.9 m (3.0 ft) to 8.2 m (27 ft) deeper January through May. Dworshak had significant reservoir elevation differences compared to Alternative A1 due to the removal of Snake River flow augmentation. From December through April the project drafted between 4.3 m (14 ft) and 12.2 m (40 ft) deeper. From May through November the reservoir was 1.2 m (4.0 ft) to 18.9 m (62 ft) higher. The average annual reservoir elevation at Dworshak lowered by 1.4 m (4.5 ft). Deeper drafts are the result of other projects attempting to replace generation lost due to drawdown.

### 5.11.3 Flows

In Alternative C2, the regulated flow at Lower Granite increases from 746.9 $m^3/s$ (26,375 cfs) in November to a peak of 2964.6 $m^3/s$ (104,694 cfs) in May and decreases back down to the lowest point of 610.8 $m^3/s$ (21,571 cfs) in August, with the exception of September and October where the regulated flow is 879.6 $m^3/s$ (31,063 cfs) and 822.2 $m^3/s$ (29,034 cfs), respectively. When compared to Alternative A1, the regulated flow at Lower Granite increased between 87.1 $m^3/s$ (3,077 cfs) and 216.3 $m^3/s$ (7,638 cfs) from September to February. The regulated flows decreased between 33.8 $m^3/s$ (1,193 cfs) and 467.7 $m^3/s$ (16,516 cfs) from the first part of April to the last part of August. Other periods changed less than 5.7 $m^3/s$ (200 cfs).

At McNary, in Alternative C2, the regulated flows increased from 2966 $m^3/s$ (104,743 cfs) in September to a peak of 7534.3 $m^3/s$ (266,073 cfs) in May and back down to the lowest flow in September, with the exception of January and February when the regulated flow was 5888.6 $m^3/s$ (207,954 cfs) and 5590 $m^3/s$ (197,409 cfs), respectively. When compared to Alternative A1, the regulated flows increased between 73.4 $m^3/s$ (2,591 cfs) and 743.5 $m^3/s$ (26,255 cfs) from September to March. The regulated flows decreased between 262.8 $m^3/s$ (9,279 cfs) and 900 $m^3/s$ (31,783 cfs) from the first part of April to the last part of August.

The Salmon Biological Opinion regulated flow objective at Lower Granite in Alternative C2 was met in 20 years during the last part of April, in 35 years during May, in 39 years during June, in 11 years in July, in 4 years in the first part of August, and in no years during the last part of August.

In Alternative C2 at McNary, the Salmon Biological Opinion flow objectives were met in 33 years during the last part of April, in 47 years during May, in 25 years during June, in 4 years during July, in 1 year during the first part of August, and in no years during the last part of August.

**Table 5-1.** System Generation (aMW)

| Alternative | AUG1 | AUG 2 | SEP | OCT | NOV | DEC | JAN | FEB | MAR | APR 1 | APR 2 | MAY | JUN | JUL | Ave Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 13196 | 10872 | 9466 | 9520 | 10414 | 14071 | 16800 | 15200 | 13820 | 14802 | 16890 | 18729 | 18834 | 13725 | 14038 |
| A2 | 13200 | 10890 | 9467 | 9533 | 10418 | 14078 | 16803 | 15203 | 13820 | 14883 | 17129 | 19049 | 19139 | 13743 | 14108 |
| A3 | 12230 | 10388 | 9046 | 8953 | 10021 | 12867 | 15987 | 14098 | 11794 | 12502 | 14372 | 16314 | 16703 | 12728 | 12771 |
| A5 | 12078 | 9699 | 9317 | 9107 | 10494 | 13253 | 16230 | 14247 | 11796 | 12468 | 14054 | 16078 | 16538 | 12450 | 12805 |
| A6a | 13265 | 11167 | 9495 | 9535 | 10401 | 14083 | 16860 | 15127 | 13801 | 14809 | 17221 | 18544 | 18879 | 13816 | 14064 |
| A6b | 13237 | 10861 | 9412 | 9504 | 10437 | 14042 | 16840 | 15088 | 13819 | 14815 | 17346 | 18578 | 18755 | 13731 | 14028 |
| B1 | 11519 | 9835 | 8703 | 8519 | 9377 | 11534 | 14535 | 12461 | 10337 | 11124 | 12830 | 14693 | 15114 | 11842 | 11647 |
| B2 | 9621 | 8880 | 8062 | 8706 | 10658 | 12285 | 15902 | 14038 | 11387 | 11064 | 11619 | 14100 | 13794 | 11289 | 11734 |
| C1 | 11898 | 10135 | 8866 | 8764 | 9767 | 12217 | 15311 | 13320 | 11045 | 11781 | 13499 | 15430 | 15820 | 12283 | 12206 |
| C2 | 10047 | 9348 | 8384 | 9085 | 11059 | 12814 | 16506 | 14992 | 12243 | 11724 | 12148 | 14419 | 14467 | 11713 | 12276 |

**Table 5-2.** Difference in System Generation (aMW)

| Alternative | AUG 1 | AUG 2 | SEP | OCT | NOV | DEC | JAN | FEB | MAR | APR 1 | APR 2 | MAY | JUN | JUL | Ave Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 - A2 | (4) | (18) | (1) | (13) | (4) | (7) | (3) | (3) | 0 | (81) | (239) | (320) | (305) | (18) | (70) |
| A1 - A3 | 966 | 484 | 420 | 567 | 393 | 1204 | 813 | 1102 | 2026 | 2300 | 2518 | 2415 | 2131 | 997 | 1267 |
| A1 - A5 | 1118 | 1173 | 149 | 413 | (80) | 818 | 570 | 953 | 2024 | 2334 | 2836 | 2651 | 2296 | 1275 | 1233 |
| A1 - A6a | (69) | (295) | (29) | (15) | 13 | (12) | (60) | 73 | 19 | (7) | (331) | 185 | (45) | (91) | (26) |
| A1 - A6b | (41) | 11 | 54 | 16 | (23) | 29 | (40) | 112 | 1 | (13) | (456) | 151 | 79 | (6) | 10 |
| A1 - B1 | 1677 | 1037 | 763 | 1001 | 1037 | 2537 | 2265 | 2739 | 3483 | 3678 | 4060 | 4036 | 3720 | 1883 | 2391 |
| A1 - B2 | 3575 | 1992 | 1404 | 814 | (244) | 1786 | 898 | 1162 | 2433 | 3738 | 5271 | 4629 | 5040 | 2436 | 2304 |
| A1 - C1 | 1298 | 737 | 600 | 756 | 647 | 1854 | 1489 | 1880 | 2775 | 3021 | 3391 | 3299 | 3014 | 1442 | 1832 |
| A1 - C2 | 3149 | 1524 | 1082 | 435 | (645) | 1257 | 294 | 208 | 1577 | 3078 | 4742 | 4310 | 4367 | 2012 | 1762 |

**Table 5-3.** Alternative A1 Generation at Lower Granite, Little Goose, Lower Monumental, and Ice Harbor (aMW)

| Facility | AUG 1 | AUG 2 | SEP | OCT | NOV | DEC | JAN | FEB | MAR | APR 1 | APR 2 | MAY | JUN | JUL | Ave Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LWG | 281 | 204 | 159 | 169 | 135 | 233 | 274 | 294 | 366 | 478 | 585 | 650 | 607 | 332 | 333 |
| LGS | 275 | 199 | 256 | 166 | 126 | 228 | 268 | 287 | 359 | 464 | 537 | 593 | 554 | 324 | 317 |
| LMN | 283 | 205 | 159 | 173 | 129 | 236 | 279 | 309 | 374 | 483 | 575 | 629 | 585 | 338 | 332 |
| IHR | 82 | 58 | 158 | 172 | 126 | 231 | 273 | 301 | 358 | 448 | 466 | 519 | 398 | 99 | 264 |
| Total Generation | 921 | 666 | 732 | 680 | 516 | 928 | 1094 | 1191 | 1457 | 1873 | 2163 | 2391 | 2144 | 1093 | 1246 |

**Table 5-4.** Libby, Hungry Horse, Grand Coulee and Dworshak Reservoir Elevations (ft)

| Alternative | AUG 1 | AUG 2 | SEP | OCT | NOV | DEC | JAN | FEB | MAR | APR 1 | APR 2 | MAY | JUN | JUL | Ave Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LIB A1 | 2442.1 | 2440.0 | 2429.6 | 2428.3 | 2425.9 | 2411.0 | 2384.0 | 2360.6 | 2350.8 | 2352.0 | 2356.9 | 2398.2 | 2425.3 | 2444.2 | 2404.5 |
| LIB A2 | 2442.0 | 2439.9 | 2429.5 | 2428.2 | 2425.9 | 2410.9 | 2383.9 | 2360.5 | 2350.7 | 2351.9 | 2356.8 | 2398.2 | 2425.1 | 2444.0 | 2404.4 |
| LIB A3 | 2442.1 | 2440.0 | 2426.4 | 2423.9 | 2421.8 | 2411.0 | 2384.1 | 2360.6 | 2350.8 | 2352.0 | 2356.8 | 2398.2 | 2425.4 | 2444.2 | 2403.5 |
| LIB A5 | 2441.5 | 2439.8 | 2428.1 | 2425.4 | 2422.5 | 2411.0 | 2384.0 | 2360.6 | 2350.8 | 2352.0 | 2356.8 | 2398.1 | 2425.4 | 2444.1 | 2403.8 |
| LIB A6a | 2441.6 | 2439.0 | 2428.8 | 2427.8 | 2425.5 | 2411.0 | 2384.0 | 2360.6 | 2350.8 | 2352.0 | 2356.9 | 2398.1 | 2425.3 | 2444.2 | 2404.3 |
| LIB A6b | 2441.9 | 2439.9 | 2429.2 | 2428.0 | 2425.6 | 2411.0 | 2384.0 | 2360.6 | 2350.8 | 2352.0 | 2356.9 | 2398.1 | 2425.3 | 2444.2 | 2404.3 |
| LIB B1 | 2442.1 | 2440.0 | 2422.8 | 2419.5 | 2416.9 | 2411.0 | 2384.7 | 2360.8 | 2351.0 | 2352.1 | 2357.0 | 2398.2 | 2425.3 | 2444.2 | 2402.5 |
| LIB B2 | 2447.8 | 2447.9 | 2449.3 | 2446.5 | 2426.8 | 2411.0 | 2384.0 | 2360.6 | 2350.7 | 2351.9 | 2356.0 | 2397.4 | 2426.1 | 2445.7 | 2408.3 |
| LIB C1 | 2442.0 | 2440.0 | 2424.7 | 2422.3 | 2419.9 | 2411.0 | 2384.3 | 2360.7 | 2350.8 | 2352.0 | 2356.9 | 2398.1 | 2425.4 | 2444.2 | 2403.1 |
| LIB C2 | 2447.8 | 2446.7 | 2447.9 | 2445.3 | 2426.4 | 2411.0 | 2384.0 | 2360.6 | 2350.8 | 2352.0 | 2356.1 | 2397.4 | 2426.1 | 2445.6 | 2408.0 |
| HGH A1 | 3545.6 | 3540.4 | 3533.7 | 3528.4 | 3526.0 | 3517.1 | 3511.0 | 3503.0 | 3495.7 | 3496.0 | 3495.4 | 3527.4 | 3547.6 | 3552.2 | 3523.4 |
| HGH A2 | 3545.6 | 3540.4 | 3533.5 | 3528.2 | 3525.7 | 3516.9 | 3510.9 | 3502.8 | 3495.5 | 3495.8 | 3495.3 | 3527.3 | 3547.6 | 3552.2 | 3523.3 |
| HGH A3 | 3545.5 | 3540.4 | 3532.8 | 3527.5 | 3525.3 | 3516.3 | 3507.2 | 3497.8 | 3492.8 | 3494.3 | 3494.7 | 3527.0 | 3547.6 | 3552.1 | 3522.0 |
| HGH A5 | 3543.9 | 3540.0 | 3533.4 | 3528.1 | 3525.9 | 3516.4 | 3508.1 | 3498.4 | 3493.4 | 3494.9 | 3495.2 | 3527.4 | 3547.2 | 3551.7 | 3522.3 |
| HGH A6a | 3544.3 | 3539.9 | 3532.5 | 3527.5 | 3525.3 | 3516.5 | 3510.4 | 3502.4 | 3495.0 | 3495.3 | 3494.8 | 3526.9 | 3547.1 | 3551.5 | 3522.7 |
| HGH A6b | 3544.9 | 3539.8 | 3532.8 | 3527.5 | 3525.2 | 3516.3 | 3510.0 | 3502.1 | 3494.8 | 3495.0 | 3494.5 | 3526.7 | 3546.9 | 3551.4 | 3522.6 |
| HGH B1 | 3545.2 | 3540.1 | 3531.9 | 3526.7 | 3524.7 | 3516.1 | 3502.6 | 3496.0 | 3492.2 | 3494.1 | 3494.3 | 3526.9 | 3547.3 | 3551.8 | 3521.1 |
| HGH B2 | 3555.5 | 3551.1 | 3546.8 | 3541.8 | 3539.6 | 3530.7 | 3512.6 | 3496.3 | 3488.1 | 3487.8 | 3489.2 | 3524.2 | 3552.1 | 3557.3 | 3527.6 |
| HGH C1 | 3545.2 | 3540.1 | 3532.1 | 3526.9 | 3524.8 | 3516.1 | 3504.8 | 3496.8 | 3492.3 | 3494.2 | 3494.6 | 3526.9 | 3547.5 | 3551.8 | 3521.4 |
| HGH C2 | 3553.7 | 3548.4 | 3544.0 | 3539.4 | 3537.5 | 3528.8 | 3513.2 | 3496.7 | 3487.4 | 3496.8 | 3487.8 | 3523.0 | 3551.1 | 3555.8 | 3526.3 |
| GCL A1 | 1281.8 | 1280.4 | 1284.9 | 1286.9 | 1285.2 | 1279.9 | 1260.6 | 1249.1 | 1244.3 | 1242.6 | 1235.0 | 1253.3 | 1282.9 | 1286.9 | 1269.5 |
| GCL A2 | 1281.8 | 1280.4 | 1284.9 | 1286.9 | 1285.2 | 1279.9 | 1260.6 | 1249.1 | 1244.3 | 1242.6 | 1235.0 | 1253.4 | 1282.9 | 1286.9 | 1269.5 |
| GCL A3 | 1281.8 | 1280.4 | 1284.3 | 1285.8 | 1283.1 | 1277.4 | 1254.1 | 1240.1 | 1240.1 | 1240.2 | 1234.8 | 1253.3 | 1282.9 | 1286.9 | 1267.2 |
| GCL A5 | 1280.9 | 1280.3 | 1284.8 | 1286.5 | 1284.8 | 1278.7 | 1254.9 | 1240.5 | 1240.3 | 1240.5 | 1234.5 | 1252.5 | 1282.8 | 1286.7 | 1267.5 |
| GCL A6a | 1280.3 | 1279.7 | 1284.8 | 1286.8 | 1285.1 | 1279.9 | 1259.8 | 1249.4 | 1244.4 | 1242.7 | 1232.2 | 1253.1 | 1281.9 | 1286.5 | 1269.1 |
| GCL A6b | 1281.6 | 1279.6 | 1284.8 | 1286.8 | 1285.1 | 1279.8 | 1259.7 | 1249.1 | 1244.3 | 1242.6 | 1232.2 | 1253.2 | 1282.8 | 1286.9 | 1269.2 |
| GCL B1 | 1281.8 | 1280.4 | 1283.7 | 1284.2 | 1280.5 | 1273.6 | 1247.7 | 1236.0 | 1239.3 | 1240.0 | 1234.7 | 1253.2 | 1282.9 | 1286.9 | 1265.5 |
| GCL B2 | 1289.1 | 1287.8 | 1288.0 | 1288.0 | 1287.9 | 1286.9 | 1257.7 | 1234.2 | 1225.1 | 1226.3 | 1226.6 | 1246.7 | 1286.0 | 1290.0 | 1267.1 |
| GCL C1 | 1281.8 | 1280.4 | 1284.0 | 1284.7 | 1281.7 | 1275.7 | 1250.6 | 1237.4 | 1239.4 | 1240.1 | 1234.7 | 1253.2 | 1282.9 | 1286.9 | 1266.2 |
| GCL C2 | 1288.9 | 1287.3 | 1288.0 | 1287.9 | 1287.7 | 1286.6 | 1258.2 | 1230.3 | 1216.8 | 1217.6 | 1218.0 | 1246.6 | 1286.0 | 1290.0 | 1265.3 |
| DWR A1 | 1547.5 | 1533.1 | 1532.9 | 1534.6 | 1539.2 | 1542.4 | 1532.8 | 1519.4 | 1511.5 | 1518.6 | 1520.8 | 1559.3 | 1580.0 | 1563.6 | 1539.6 |
| DWR A2 | 1547.5 | 1533.2 | 1532.9 | 1534.6 | 1539.2 | 1542.4 | 1532.8 | 1519.4 | 1511.5 | 1518.6 | 1520.8 | 1559.3 | 1580.0 | 1563.6 | 1539.6 |
| DWR A3 | 1545.0 | 1530.9 | 1530.6 | 1532.3 | 1537.0 | 1540.3 | 1532.1 | 1518.9 | 1511.1 | 1518.3 | 1520.5 | 1559.5 | 1579.6 | 1561.0 | 1538.3 |
| DWR A5 | 1591.4 | 1591.1 | 1558.8 | 1553.4 | 1517.7 | 1502.7 | 1474.9 | 1461.7 | 1461.6 | 1472.9 | 1493.2 | 1559.0 | 1590.9 | 1592.3 | 1528.9 |
| DWR A6a | 1542.7 | 1529.2 | 1528.9 | 1530.6 | 1535.4 | 1539.1 | 1531.5 | 1518.5 | 1510.5 | 1517.9 | 1524.0 | 1564.7 | 1591.3 | 1562.4 | 1539.2 |
| DWR A6b | 1532.5 | 1518.6 | 1518.3 | 1520.0 | 1524.9 | 1529.3 | 1522.7 | 1512.0 | 1505.3 | 1513.0 | 1515.3 | 1554.2 | 1576.6 | 1557.0 | 1530.0 |
| DWR B1 | 1544.9 | 1530.9 | 1530.6 | 1532.3 | 1537.0 | 1540.3 | 1532.1 | 1518.9 | 1511.1 | 1518.3 | 1520.5 | 1559.8 | 1579.9 | 1561.4 | 1538.4 |
| DWR B2 | 1596.0 | 1595.1 | 1577.4 | 1573.1 | 1554.3 | 1528.5 | 1499.9 | 1479.1 | 1474.3 | 1482.7 | 1499.5 | 1562.1 | 1595.6 | 1598.5 | 1544.1 |
| DWR C1 | 1544.9 | 1530.9 | 1530.7 | 1532.3 | 1537.0 | 1540.3 | 1532.1 | 1518.9 | 1511.1 | 1518.3 | 1520.5 | 1559.0 | 1579.8 | 1561.4 | 1538.3 |
| DWR C2 | 1595.9 | 1595.0 | 1577.0 | 1572.7 | 1554.0 | 1528.2 | 1500.1 | 1479.3 | 1474.2 | 1482.8 | 1499.6 | 1563.2 | 1595.9 | 1598.4 | 1544.1 |

**Table 5-5.** Difference in Libby, Hungry Horse, Grand Coulee and Dworshak Reservoir Elevations (ft)

| Alternative | AUG 1 | AUG 2 | SEP | OCT | NOV | DEC | JAN | FEB | MAR | APR 1 | APR 2 | MAY | JUN | JUL | Ave Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LIB A1 - A2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.2 | 0.2 | 0.1 |
| LIB A1 - A3 | 0.0 | 0.0 | 3.2 | 4.4 | 4.1 | 0.0 | (0.1) | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | (0.1) | 0.0 | 1.0 |
| LIB A1 - A5 | 0.6 | 0.2 | 1.5 | 2.9 | 3.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | (0.1) | 0.1 | 0.7 |
| LIB A1 - A6a | 0.0 | 0.0 | 0.2 | 0.1 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.2 | 0.2 | 0.2 | 0.2 |
| LIB A1 - A6b | 0.2 | 0.1 | 0.4 | 0.3 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | [illegible] | 0.1 | 0.0 | 0.0 | 0.2 |
| LIB A1 - B1 | 0.0 | 0.0 | 6.8 | 8.8 | 9.0 | 0.0 | (0.7) | (0.2) | (0.2) | (0.1) | (0.1) | 0.0 | 0.0 | 0.0 | 2.0 |
| LIB A1 - B2 | (5.7) | (7.9) | (19.7) | (18.2) | (0.9) | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.9 | 0.8 | (0.8) | (1.5) | (3.8) |
| LIB A1 - C1 | 0.1 | 0.0 | 4.9 | 6.0 | 6.0 | 0.0 | (0.3) | (0.1) | 0.0 | 0.0 | 0.0 | 0.1 | (0.1) | 0.0 | 1.4 |
| LIB A1 - C2 | (5.7) | (6.7) | (18.3) | (17.0) | (0.5) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 | 0.8 | (0.8) | (1.4) | (3.5) |
| | | | | | | | | | | | | | | | |
| HGH A1 - A2 | 0.0 | 0.0 | 0.2 | 0.2 | 0.3 | 0.2 | 0.1 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.0 | 0.0 | 0.1 |
| HGH A1 - A3 | 0.1 | 0.0 | 0.9 | 0.9 | 0.7 | 0.8 | 3.8 | 5.2 | 2.9 | 1.7 | 0.7 | 0.4 | 0.0 | 0.1 | 1.4 |
| HGH A1 - A5 | 1.7 | 0.4 | 0.3 | 0.3 | 0.1 | 0.7 | 2.9 | 4.6 | 2.3 | 1.1 | 0.2 | 0.0 | 0.4 | 0.5 | 1.1 |
| HGH A1 - A6a | 0.0 | (0.1) | 0.7 | 0.7 | 0.6 | 0.6 | 0.7 | 0.6 | 0.7 | 0.7 | 0.6 | 0.5 | 0.0 | 0.1 | 0.5 |
| HGH A1 - A6b | 0.7 | 0.6 | 0.9 | 0.9 | 0.8 | 0.8 | 1.0 | 0.9 | 0.9 | 1.0 | 0.9 | 0.7 | 0.7 | 0.8 | 0.8 |
| HGH A1 - B1 | 0.4 | 0.3 | 1.8 | 1.7 | 1.3 | 1.0 | 8.4 | 7.0 | 3.5 | 1.9 | 1.1 | 0.5 | 0.3 | 0.4 | 2.3 |
| HGH A1 - B2 | (9.9) | (10.7) | (13.1) | (13.4) | (13.6) | (13.6) | (1.6) | 6.7 | 7.6 | 8.2 | 6.2 | 3.2 | (4.5) | (5.1) | (4.2) |
| HGH A1 - C1 | 0.4 | 0.3 | 1.6 | 1.5 | 1.2 | 1.0 | 6.2 | 6.2 | 3.4 | 1.8 | 0.8 | 0.5 | 0.1 | 0.4 | 2.0 |
| HGH A1 - C2 | (8.1) | (8.0) | (10.3) | (11.0) | (11.5) | (11.7) | (2.2) | 6.3 | 8.3 | (0.8) | 7.6 | 4.4 | (3.5) | (3.6) | (2.9) |
| | | | | | | | | | | | | | | | |
| GCL A1 - A2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | (0.1) | 0.0 | 0.0 | 0.0 |
| GCL A1 - A3 | 0.0 | 0.0 | 0.6 | 1.1 | 2.1 | 2.5 | 6.5 | 9.0 | 4.2 | 2.4 | 0.2 | 0.0 | 0.0 | 0.0 | 2.3 |
| GCL A1 - A5 | 0.9 | 0.1 | 0.1 | 0.4 | 0.4 | 1.2 | 5.7 | 8.6 | 4.0 | 2.1 | 0.5 | 0.8 | 0.1 | 0.2 | 2.0 |
| GCL A1 - A6a | (0.2) | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 | (0.1) | 0.0 | 0.0 | 2.8 | (0.1) | 0.8 | 0.5 | 0.3 |
| GCL A1 - A6b | 0.2 | 0.8 | 0.1 | 0.1 | 0.1 | 0.1 | 0.9 | 0.0 | 0.0 | 0.0 | 2.8 | 0.1 | 0.1 | 0.0 | 0.3 |
| GCL A1 - B1 | 0.0 | 0.0 | 1.2 | 2.7 | 4.7 | 6.3 | 12.9 | 13.1 | 5.0 | 2.6 | 0.3 | 0.1 | 0.0 | 0.0 | 4.0 |
| GCL A1 - B2 | (7.3) | (7.4) | (3.1) | (1.1) | (2.7) | (7.0) | 2.9 | 14.9 | 19.2 | 16.3 | 8.4 | 6.6 | (3.1) | (3.1) | 2.4 |
| GCL A1 - C1 | 0.0 | 0.0 | 0.9 | 2.2 | 3.5 | 4.2 | 10.0 | 11.7 | 4.9 | 2.5 | 0.3 | 0.1 | 0.0 | 0.0 | 3.3 |
| GCL A1 - C2 | (7.1) | (6.9) | (3.1) | (1.0) | (2.5) | (6.7) | 2.4 | 18.8 | 27.5 | 25.0 | 17.0 | 6.7 | (3.1) | (3.1) | 4.2 |
| | | | | | | | | | | | | | | | |
| DWR A1 - A2 | 0.0 | (0.1) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DWR A1 - A3 | 2.5 | 2.2 | 2.3 | 2.3 | 2.2 | 2.1 | 0.7 | 0.5 | 0.4 | 0.3 | 0.3 | (0.2) | 0.4 | 2.6 | 1.3 |
| DWR A1 - A5 | (43.9) | (58.0) | (25.9) | (18.8) | 21.5 | 39.7 | 57.9 | 57.7 | 49.9 | 45.7 | 27.6 | 0.3 | (10.9) | (28.7) | 10.7 |
| DWR A1 - A6a | (3.8) | 0.4 | 0.4 | 0.5 | 0.5 | 1.1 | 0.3 | 0.3 | 0.3 | 0.2 | (3.8) | (11.8) | (16.3) | (6.0) | (2.9) |
| DWR A1 - A6b | 15.0 | 14.5 | 14.6 | 14.6 | 14.3 | 13.1 | 10.1 | 7.4 | 6.2 | 5.6 | 5.5 | 5.1 | 3.4 | 6.6 | 9.6 |
| DWR A1 - B1 | 2.6 | 2.2 | 2.3 | 2.3 | 2.2 | 2.1 | 0.7 | 0.5 | 0.4 | 0.3 | 0.3 | (0.5) | 0.1 | 2.2 | 1.2 |
| DWR A1 - B2 | (48.5) | (62.0) | (44.5) | (38.5) | (15.1) | 13.9 | 32.9 | 40.3 | 37.2 | 35.9 | 21.3 | (2.8) | (15.6) | (34.9) | (4.5) |
| DWR A1 - C1 | 2.6 | 2.2 | 2.2 | 2.3 | 2.2 | 2.1 | 0.7 | 0.5 | 0.4 | 0.3 | 0.3 | 0.3 | 0.2 | 2.2 | 1.3 |
| DWR A1 - C2 | (48.4) | (61.9) | (44.1) | (38.1) | (14.8) | 14.2 | 32.7 | 40.1 | 37.3 | 35.8 | 21.2 | (3.9) | (15.9) | (34.8) | (4.5) |

**Table 5-6.** Lower Granite Regulated Flow (cfs)

| Alternative | AUG 1 | AUG 2 | SEP | OCT | NOV | DEC | JAN | FEB | MAR | APR 1 | APR 2 | MAY | JUN | JUL | Ave Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Natural Flow | 22,992 | 20,701 | 22,548 | 25,293 | 28,950 | 33,461 | 34,604 | 39,665 | 49,829 | 73,196 | 91,287 | 121,483 | 110,485 | 40,559 | 50,914 |
| A1 | 41,418 | 30,212 | 23,751 | 25,197 | 19,598 | 32,417 | 38,072 | 40,780 | 51,071 | 71,829 | 96,549 | 109,972 | 101,397 | 48,838 | 50,925 |
| A2 | 41,441 | 30,212 | 23,751 | 25,197 | 19,584 | 32,431 | 38,076 | 40,780 | 51,071 | 71,829 | 96,549 | 109,975 | 101,395 | 48,833 | 50,926 |
| A3 | 41,268 | 29,987 | 23,751 | 25,197 | 20,371 | 32,327 | 37,735 | 40,737 | 51,065 | 70,394 | 96,557 | 109,799 | 101,647 | 49,375 | 50,926 |
| A5 | 24,159 | 21,196 | 34,666 | 29,207 | 29,777 | 37,091 | 40,366 | 46,116 | 50,568 | 70,000 | 84,200 | 104,316 | 98,637 | 41,043 | 50,964 |
| A6a | 47,994 | 37,988 | 22,679 | 25,272 | 18,925 | 32,020 | 37,969 | 40,787 | 50,556 | 72,003 | 94,779 | 110,663 | 103,754 | 51,667 | 51,723 |
| A6b | 42,447 | 27,678 | 23,105 | 25,585 | 20,611 | 33,391 | 38,208 | 40,593 | 51,314 | 72,351 | 96,987 | 110,161 | 100,838 | 47,291 | 50,903 |
| B1 | 41,435 | 29,984 | 23,751 | 25,197 | 20,425 | 32,274 | 37,735 | 40,737 | 51,065 | 70,394 | 96,557 | 109,721 | 101,644 | 49,377 | 50,926 |
| B2 | 24,906 | 21,530 | 30,995 | 29,043 | 26,403 | 40,063 | 41,239 | 47,573 | 51,192 | 70,687 | 85,350 | 104,978 | 98,060 | 40,567 | 50,946 |
| C1 | 41,463 | 29,946 | 23,751 | 25,197 | 20,419 | 32,281 | 37,735 | 40,739 | 51,065 | 70,394 | 96,557 | 109,240 | 102,176 | 49,347 | 50,928 |
| C2 | 24,902 | 21,571 | 31,063 | 29,034 | 26,375 | 40,055 | 41,149 | 47,558 | 51,251 | 70,636 | 85,339 | 104,694 | 98,265 | 40,689 | 50,947 |

**Table 5-7.** McNary Regulated Flow (cfs)

| Alternative | AUG 1 | AUG 2 | SEP | OCT | NOV | DEC | JAN | FEB | MAR | APR 1 | APR 2 | MAY | JUN | JUL | Ave Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Natural Flow | 150,664 | 117,495 | 93,184 | 82,959 | 84,681 | 87,559 | 84,906 | 95,759 | 116,335 | 175,051 | 251,184 | 415,532 | 463,462 | 251,428 | 176,887 |
| A1 | 170,177 | 132,419 | 101,254 | 103,051 | 103,443 | 147,979 | 189,872 | 171,154 | 164,013 | 188,382 | 239,090 | 279,741 | 274,515 | 180,160 | 173,352 |
| A2 | 170,185 | 132,553 | 101,183 | 103,196 | 103,420 | 148,021 | 189,894 | 171,173 | 164,005 | 188,294 | 238,356 | 279,372 | 274,841 | 180,302 | 173,342 |
| A3 | 169,610 | 135,372 | 103,006 | 104,597 | 106,972 | 145,522 | 194,060 | 173,406 | 157,766 | 179,508 | 234,076 | 279,002 | 275,364 | 181,782 | 173,397 |
| A5 | 156,241 | 123,243 | 110,349 | 108,527 | 115,271 | 151,747 | 197,718 | 179,347 | 157,649 | 179,114 | 223,219 | 274,055 | 271,852 | 173,816 | 173,437 |
| A6a | 174,171 | 141,026 | 100,459 | 103,043 | 102,685 | 147,806 | 190,642 | 170,218 | 163,448 | 188,555 | 244,053 | 277,808 | 277,490 | 182,255 | 174,147 |
| A6b | 170,898 | 130,958 | 100,177 | 103,222 | 104,416 | 148,425 | 190,871 | 169,988 | 164,132 | 188,772 | 246,178 | 277,613 | 273,806 | 179,124 | 173,348 |
| B1 | 170,140 | 135,861 | 106,797 | 107,864 | 108,921 | 143,128 | 195,228 | 169,797 | 153,637 | 178,792 | 233,787 | 278,820 | 275,364 | 181,776 | 173,386 |
| B2 | 136,950 | 118,834 | 105,184 | 111,314 | 121,665 | 150,866 | 209,626 | 193,612 | 168,325 | 178,215 | 210,059 | 272,758 | 257,464 | 168,585 | 173,453 |
| C1 | 170,004 | 135,746 | 104,606 | 105,887 | 108,281 | 144,178 | 195,397 | 172,063 | 155,168 | 178,648 | 233,939 | 278,435 | 275,733 | 181,812 | 173,395 |
| C2 | 138,394 | 121,124 | 104,743 | 111,009 | 121,160 | 150,570 | 207,954 | 197,409 | 172,067 | 179,103 | 209,826 | 266,073 | 257,595 | 168,977 | 173,482 |

**Table 5-8.** Difference in Lower Granite Regulated Flow (cfs)

| Alternative | AUG 1 | AUG 2 | SEP | OCT | NOV | DEC | JAN | FEB | MAR | APR 1 | APR 2 | MAY | JUN | JUL | Ave Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 - A2 | (23) | 0 | 0 | 0 | 14 | (14) | (4) | 0 | 0 | 0 | 0 | (3) | 2 | 5 | (1) |
| A1 - A3 | 150 | 225 | 0 | 0 | (773) | 90 | 337 | 43 | 6 | 1,435 | (8) | 173 | (250) | (537) | (1) |
| A1 - A5 | 17,259 | 9,016 | (10,915) | (4,010) | (10,179) | (4,674) | (2,294) | (5,336) | 503 | 1,829 | 12,349 | 5,656 | 2,760 | 7,795 | (39) |
| A1 - A6a | (6,576) | (7,776) | 1,072 | (75) | 673 | 397 | 103 | (7) | 515 | (174) | 1,770 | (691) | (2,357) | (2,829) | (798) |
| A1 - A6b | (1,029) | 2,534 | 646 | (388) | (1,013) | (974) | (136) | 187 | (243) | (522) | (438) | (189) | 559 | 1,547 | 22 |
| A1 - B1 | (17) | 228 | 0 | 0 | (827) | 143 | 337 | 43 | 6 | 1,435 | (8) | 251 | (247) | (539) | (1) |
| A1 - B2 | 16,512 | 8,682 | (7,244) | (3,846) | (6,805) | (7,646) | (3,167) | (6,793) | (121) | 1,142 | 11,199 | 4,994 | 3,337 | 8,271 | (21) |
| A1 - C1 | (45) | 266 | 0 | 0 | (821) | 136 | 337 | 41 | 6 | 1,435 | (8) | 732 | (779) | (509) | (3) |
| A1 - C2 | 16,516 | 8,641 | (7,312) | (3,837) | (6,777) | (7,638) | (3,077) | (6,778) | (180) | 1,193 | 11,210 | 5,278 | 3,132 | 8,149 | (22) |

**Table 5-9.** Difference in McNary Regulated Flow (cfs)

| Alternative | AUG 1 | AUG 2 | SEP | OCT | NOV | DEC | JAN | FEB | MAR | APR 1 | APR 2 | MAY | JUN | JUL | Ave Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 - A2 | (8) | (134) | 71 | (145) | 23 | (42) | -22 | (19) | 8 | 88 | 734 | 369 | (326) | (142) | 10 |
| A1 - A3 | 567 | (2,953) | (1,752) | (1,546) | (3,529) | 2,457 | (4,188) | (2,252) | 6,247 | 8,874 | 5,014 | 739 | (849) | (1,622) | (45) |
| A1 - A5 | 13,936 | 9,176 | (9,095) | (5,476) | (11,828) | (3,768) | (7,846) | (8,193) | 6,364 | 9,268 | 15,871 | 5,686 | 2,663 | 6,344 | (85) |
| A1 - A6a | (3,994) | (8,607) | 795 | 8 | 758 | 173 | (770) | 936 | 565 | (173) | (4,963) | 1,933 | (2,975) | (2,095) | (795) |
| A1 - A6b | (721) | 1,461 | 1,077 | (171) | (973) | (446) | (999) | 1,166 | (119) | (390) | (7,088) | 2,128 | 709 | 1,036 | 4 |
| A1 - B1 | 37 | (3,442) | (5,543) | (4,813) | (5,478) | 4,851 | (5,356) | 1,357 | 10,376 | 9,590 | 5,303 | 921 | (849) | (1,616) | (34) |
| A1 - B2 | 33,227 | 13,585 | (3,930) | (8,263) | (18,222) | (2,887) | (19,754) | (22,458) | (4,312) | 10,167 | 29,031 | 6,983 | 17,051 | 11,575 | (101) |
| A1 - C1 | 173 | (3,327) | (3,352) | (2,836) | (4,838) | 3,801 | (5,525) | (909) | 8,845 | 9,734 | 5,151 | 1,306 | (1,218) | (1,652) | (43) |
| A1 - C2 | 31,783 | 11,295 | (3,489) | (7,958) | (17,717) | (2,591) | (18,082) | (26,255) | (8,054) | 9,279 | 29,264 | 13,668 | 16,920 | 11,183 | (130) |

**Table 5-10.** Years Lower Granite Flow Objectives were Met (Number of Years Out of Sixty)

| Alternative | AUG 1 | AUG 2 | SEP | OCT | NOV | DEC | JAN | FEB | MAR | APR 1 | APR 2 | MAY | JUN | JUL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Natural Flow | 0 | 0 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 24 | 44 | 44 | 11 |
| A1 | 4 | 0 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 27 | 39 | 39 | 18 |
| A2 | 4 | 0 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 27 | 40 | 39 | 18 |
| A3 | 4 | 0 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 27 | 41 | 41 | 21 |
| A5 | 0 | 0 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 19 | 34 | 39 | 11 |
| A6a | 6 | 0 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 29 | 43 | 43 | 19 |
| A6b | 3 | 0 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 28 | 39 | 40 | 13 |
| B1 | 4 | 0 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 27 | 41 | 39 | 23 |
| B2 | 0 | 0 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 20 | 35 | 38 | 11 |
| C1 | 4 | 0 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 27 | 40 | 41 | 22 |
| C2 | 4 | 0 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 20 | 35 | 39 | 11 |

Note: See Section 4.2.4.2

**Table 5-11.** Years McNary Flow Objectives were Met (Number of Years Out of Sixty)

| Alternative | AUG 1 | AUG 2 | SEP | OCT | NOV | DEC | JAN | FEB | MAR | APR 1 | APR 2 | MAY | JUN | JUL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Natural Flow | 1 | 0 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 42 | 60 | 60 | 29 |
| A1 | 1 | 0 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 40 | 57 | 28 | 5 |
| A2 | 1 | 0 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 40 | 57 | 28 | 5 |
| A3 | 1 | 0 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 40 | 57 | 35 | 5 |
| A5 | 1 | 0 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 37 | 54 | 29 | 4 |
| A6a | 1 | 0 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 47 | 54 | 39 | 5 |
| A6b | 1 | 0 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 47 | 54 | 31 | 5 |
| B1 | 1 | 0 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 40 | 57 | 34 | 5 |
| B2 | 1 | 0 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 33 | 50 | 25 | 4 |
| C1 | 1 | 0 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 40 | 57 | 33 | 5 |
| C2 | 1 | 0 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 33 | 47 | 25 | 4 |

Note: See Section 4.2.4.1

# 6. Glossary

**Acre-foot:** The volume of water that will cover an area of one acre to a depth of one foot (326,000 gallons or 0.5 second foot days). It equals 1,233.5 m3.

**Actual Energy Capability (AEC):** Each PNCA party's generating capability based on operating the coordinated system's reservoirs to the energy content curve or to proportional draft points.

**Actual Energy Regulation (AER):** Hydro regulation study used to determine each party's Actual Energy Capability.

**Anadromous fish:** Fish, such as salmon or steelhead trout, that hatch in fresh water, migrate to and mature in the ocean, and return to fresh water as adults to spawn.

**Annual operating plan:** A yearly plan for operating reservoirs on the Columbia River. Such a plan is specifically required by the Columbia River Treaty and by the Pacific Northwest Coordination Agreement.

**Assured Operating Plan:** A study mandated by the Columbia River Treaty that determines U.S. and Canadian benefits of Treaty projects.

**Assured refill curve (ARC):** A representation of the lowest drawdown level from which a reservoir could refill given a repetition of the third-lowest runoff year of record.

**Average megawatt (aMW):** The average amount of energy (in megawatts) supplied or demanded over a specified period of time; equivalent to the energy produced by the continuous operation of one megawatt of capacity over the specified period.

**Baseload:** In a demand sense, a load that varies only slightly in level over a specified time period. In a supply sense, a plant that operates most efficiently at a relatively constant level of generation.

**Bypass system:** Structure in a dam that provides a route for fish to move through or around the dam without going through the turbines.

**Canadian Entitlement:** Canada's share of hydropower generated at downstream projects by the use of the Columbia River Treaty projects.

**Canadian Entitlement Allocation Agreements:** Contracts that specify how much power is to be provided by five mid-Columbia projects as a result of increased flows made possible by the Columbia River Treaty projects.

**Capacity:** The maximum sustainable amount of power that can be produced by a generating resource at specified times under specified conditions or carried by a transmission facility; also, the maximum rate at which power can be saved by a nongenerating resource.

**Capacity/energy exchange:** A transaction in which one utility provides another with capacity service in exchange for additional amounts of firm energy (exchange energy) or money, under specified conditions, usually during off-peak hours.

**Columbia River Treaty:** U.S.-Canadian agreement for bilateral development and management of the Columbia River to achieve flood control and increased power production.

**Columbia Storage Power Exchange (CSPE):** A non-profit corporation of 11 Northwest utilities that issued revenue bonds to purchase the Canadian Entitlement and sell it to 41 Northwest utilities through a Bonneville Power Administration exchange agreement.

**Composite Reservoir:** A PNCA operational procedure that simplifies in-lieu energy transactions by treating federal upstream reservoirs as one reservoir located at Grand Coulee and assuming the same flow time between these upstream reservoirs and the mid-Columbia projects.

**Coordinated operation:** The operation of interconnected electrical systems to achieve greater reliability and economy; as applied to hydro resources, the operation of a group of hydro plants to obtain optimal power benefits.

**Content:** An amount of water stored in a reservoir, usually expressed in terms of ksfd or MAF.

**Critical period:** That portion of the historical 50-year streamflow record which, when combined with the drafting of all storage reservoirs from full to empty, would produce the least amount of energy shaped to seasonal load patterns.

**Critical rule curves (CRC):** A set of curves that define reservoir elevations that must be maintained to ensure that firm energy requirements can be met under the most adverse historical streamflow conditions. Critical rule curves are derived for all years in the critical period. They are used for proportional draft of reservoirs.

**Critical water:** Streamflows which occurred during the critical period.

**Cubic foot per second (cfs):** A unit of measurement pertaining to flow or discharge of water. One cfs is equal to 449 gallons per minute. A thousand cubic ft per second is abbreviated as kcfs.

**Demand:** The rate at which electric energy is used, whether at a given instant, or averaged over any designated period of time.

**Discharge:** Volume of water released from a dam or powerhouse at a given time, usually expressed in cubic ft per second.

**Displacement:** The substitution of less-expensive energy generation for more-expensive energy generation (usually hydroelectric energy transmitted from the Pacific Northwest or Canada is substituted for more expensive coal and oil-fired generation in California). Such displacement usually means that a thermal plant can reduce or shut down its production, saving money and often reducing air pollution.

**Draft:** Release of water from a storage reservoir.

**Drawdown:** The distance that the water surface of a reservoir is lowered from a given elevation as water is released from the reservoir. Also refers to the act of lowering reservoir levels. (Similar to draft.)

**Elevation:** Height in ft above sea level. Usually refers to reservoir forebay; used interchangeably with content because a forebay elevation implies a specific reservoir content. Tailwater level is also expressed as an elevation.

**Energy:** The ability to do work (i.e., exert a force over distance). Energy is measured in calories, joules, KWh, BTUs, MW-hours, and average MWs.

**Energy content curves (ECC):** A set of curves that establishes limits on the amount of reservoir drawdown permitted to produce energy in excess of FELCC.

**FELCC:** Firm energy load carrying capability (FELCC) is the amount of energy the region's generating system, or an individual utility or project, can be called on to produce on a firm basis during actual operations. FELCC is made up of both hydro and non-hydro resources, including power purchases.

**Firm energy:** The amount of energy that can be generated given the region's worst historical water conditions. It is energy produced on a guaranteed basis.

**Fish ladders:** A series of ascending pools constructed to enable salmon or other fish to swim upstream around or over a dam.

**Fish passage facilities:** Features of a dam that enable fish to move around, through, or over without harm. Generally an upstream fish ladder or a downstream bypass system.

**Fixed drawdown period:** The late summer and fall when the volume of the next spring runoff is not yet known, and reservoir operations are guided by fixed rule curves based on historical streamflow patterns.

**Flood control rule curve:** A curve, or family of curves, indicating the minimum reservoir drawdown required to control floods. (Also called Mandatory Rule Curve or Upper Rule Curve).

**Flow:** The volume of water passing a given point per unit of time. Same as streamflow.

**Forced outage:** An unforeseen outage that results from emergency conditions.

**Forced outage reserves:** Peak generating capability planned to be available to serve peak loads during forced outages of generating units.

**Forebay:** The portion of a reservoir at a hydroelectric plant that is immediately upstream of a dam or powerhouse.

**Forebay elevation:** Height of top of the forebay above sea level.

**Freshet:** A rapid temporary rise in streamflow caused by heavy rains or rapid snowmelt.

**Generation:** Act or process of producing electric energy from other forms of energy. Also refers to the amount of electric energy so produced.

**Headwater benefits:** Gains in usable downstream energy as a result of upstream storage.

**Historical streamflow record:** The unregulated streamflow data base of the 50 years beginning in July 1928; data are modified to adjust for factors such as irrigation depletions and evaporations for the particular operating year being studied.

**Hydraulic Head:** The vertical distance between the surface of the reservoir and the surface of the river immediately downstream from the powerhouse. Head is the difference between forebay and tailwater elevations.

**Hydroelectricity:** The production of electric power through use of the gravitational force of falling water.

**Hydrology:** The science dealing with the continuous cycle of evapotranspiration, precipitation, and runoff.

**Hydrometeorological observations:** Data that combine snowpack measurements and climatic forecasts to predict runoff.

**Inflow:** Water that flows into a reservoir or forebay during a specified period.

**In-lieu energy:** Energy provided by a reservoir owner instead of water to which a downstream party is entitled.

**Intake:** The entrance to a conduit through a dam or water facility.

**Interchange energy:** Electric energy received by one utility system usually in exchange for energy to be delivered to another system at another time or place. Interchange energy is different from a direct purchase or sale, although accumulated energy balances are sometimes settled in cash.

**Interruptible:** A supply of power which, by agreement, can be shut off on relatively short notice (from minutes to a few days).

**KAF:** A thousand acre ft; same as .504 thousand second foot days.

**kcfs:** A measurement of water flow equivalent to 1,000 cubic ft of water passing a given point for an entire second.

**ksfd:** A volume of water equal to 1,000 cubic ft of water flowing past a point for an entire day. Same as 1.98 KAF.

**Levee:** An embankment constructed to prevent a river from overflowing.

**Load:** The amount of electric power or energy delivered or required at any specified point or points on a system. Load originates primarily at the energy-consuming equipment of customers.

**Lock:** A chambered structure on a waterway closed off with gates for the purpose of raising or lowering the water level within the lock chamber so ships can move from one elevation to another along the waterway.

**MAF:** Million acre ft. The equivalent volume of water that will cover an area of one million acres to a depth of one foot. One MAF equals 1,000 KAF.

**Mainstem:** The principal river in a basin, as opposed to the tributary streams and smaller rivers that feed into it.

**Megawatt-hour (MWh):** A unit of electrical energy equal to one megawatt of power applied for one hour.

**Megawatts (MW):** A megawatt is one million watts, a measure of electrical power or generating capacity. A megawatt will typically serve about 1,000 people. The Dalles Dam produces an average of about 1,000 megawatts.

**Mid-Columbia:** The section of the Columbia River from Grand Coulee Dam to its junction with the Snake River.

**Nitrogen supersaturation:** A condition of water in which the concentration of dissolved nitrogen exceeds the saturation level of water. Excess nitrogen can harm the circulatory systems of fish.

**Nonfirm energy:** Energy in excess of firm energy, which is available when water conditions are better than those in the critical period; generally such energy is sold on an interruptible (nonguaranteed) basis. Also called secondary energy.

**Non-power operating requirements:** Operating requirements at hydroelectric projects that pertain to navigation, flood control, fish and wildlife, recreation, irrigation, and other non-power uses of the river.

**Northwest Power Pool Coordinating Group:** An operating group made up of BPA, the Corps, BoR, and public and private generating utilities in the Northwest. One of the group's functions is administering the Pacific Northwest Coordination Agreement.

**Off-peak hours:** Period of relatively low demand for electrical energy, as specified by the supplier (such as the middle of the night).

**Operating limits:** Also called operating requirements or constraints. Limits or requirements that must be factored into the planning process for operating reservoirs and generating projects. (Also see non-power operating requirements and operating requirements).

**Operating procedure:** Alternative method substituted for a provision in the PNCA contract by agreement of parties, clarification of the contract, or method for carrying out a procedure.

**Operating requirements:** Guidelines and limits that must be followed in the operation of a reservoir or generating project. These requirements may originate from authorizing legislation, physical plant limitations, environmental impact analysis, or input from government agencies and other entities representing specific river uses. Operating requirements are submitted annually to the Northwest Power Pool by project owners for planning purposes.

**Operating rule curve:** A composite curve, derived from a family of curves, indicating how a reservoir is to be operated under specific conditions. The operating rule curve accounts for multiple operating objectives, including flood control, hydropower generation, releases for fish migration, and refill.

**Operating year:** The 12-month period from August 1 through July 31.

**Outage:** In a power system, the state of a component (such as a generating unit, transmission line, etc.) when it is not available to perform its function due to some event directly associated with the component.

**Outflow:** The water that is released from a project during a specified period.

**Pacific Northwest Coordination Agreement:** A binding agreement among BPA, the Corps, BoR, and the major hydro generating utilities in the Pacific Northwest that stemmed from the Columbia River Treaty. The Agreement specifies a multitude of operating rules, criteria, and procedures for coordinating operation of the Pacific Northwest hydropower system for power production. It directs operation of major generating facilities as though they belonged to a single owner.

**Peak load:** The maximum electrical demand in a stated period of time. It may be the maximum instantaneous load or the maximum average load within a designated period of time.

**Project:** Run-of-river or storage dam and related facilities; also a diversion facility.

**Project outflow:** The volume of water per unit of time released from a project. Same as discharge and outflow.

**Proportional draft:** A condition in which all reservoirs are drafted among rule curves in the same proportion to meet firm loads.

**Proportional draft point (PDP):** Reservoir elevation that guides operations whenever drafting to the ECC will not produce FELCC; all reservoirs' PDPs are the same proportional distance between the critical rule curves unless restricted by NPRs.

**Provisional energy:** Energy produced by drafting below the ECC or PDP and delivered under contracts which provide for the return of the energy to the delivering utility under certain conditions. Provisional energy is called Advance Energy in contracts between BPA and its direct service industrial customers.

**Refill:** The point at which the hydro system is considered "full" from the seasonal snowmelt runoff. Also, refers to the annual process of filling a reservoir.

**Reliability:** For a power system, a measure of the degree of certainty that the system will continue to meet load for a specified period of time.

**Reregulation:** Storing erratic discharges of water from an upstream hydroelectric plant and releasing them uniformly from a downstream storage plant.

**Reregulating reservoir:** A reservoir located downstream from a hydroelectric peaking plant having sufficient pondage to store the widely fluctuating discharges from the peaking plant and release them in a relatively uniform manner downstream.

**Reservoir content:** See content and reservoir storage.

**Reservoir draft rate:** The rate at which water, released from storage behind a dam, reduces the elevation of the reservoir.

**Reservoir elevation:** The height above sea level of the water stored behind a dam. Same as forebay elevation.

**Reservoir storage:** The volume of water in a reservoir at a given time. Same as reservoir content. Reservoir storage implies a reservoir elevation. Tables are used to convert content to elevation at each - reservoir.

**Resident fish:** Fish species that reside in fresh water throughout their lives.

**Restoration:** Adjustments that permit all PNCA projects to carry the same firm energy load with as without Canadian Treaty storage; projects losing load-carrying capability are restored by projects gaining capability.

**Rule curves:** Water levels, represented graphically as curves, that guide reservoir operations. See critical rule curves, energy content curves, and flood control rule curves.

**Run-of-river dams:** Hydroelectric generating plants that operate based only on available inflow and a limited amount of short-term storage (daily/weekly pondage).

**Secondary energy:** Hydroelectric energy in excess of firm energy, often used to displace thermal resources. Sometimes called nonfirm energy.

**Secretary's Principles:** The framework of rights and obligations that forms the basis of PNCA.

**Shaping:** The scheduling and operation of generating resources to meet seasonal and hourly load variations. Load shaping on a hydro system usually involves the adjustment of reservoir releases so that generation and load are continuously in balance.

**Shifting:** In planning, moving surplus or deficit FELCC from one year of the critical period to another to increase the FELCC's value.

**Smolt:** A juvenile salmon or steelhead migrating to the ocean and undergoing physiological changes to adapt its body from a freshwater to a saltwater environment.

**Spawning:** The releasing and fertilizing of eggs by fish.

**Spill:** Water passed over a spillway without going through turbines to produce electricity. Spill can be forced, when there is no storage capability and flows exceed turbine capacity, or planned, for example, when water is spilled to enhance juvenile fish survival.

**Spillway:** Overflow structure of a dam.

**Storage energy:** The energy equivalent of water stored in a reservoir above normal bottom elevation.

**Storage reservoirs:** Reservoirs that have space for retaining water from springtime snowmelts. Careful scheduling of reservoir refill serves to prevent floods in high runoff years. Retained water is released as necessary for multiple uses - power production, fish passage, irrigation, and navigation.

**Streamflow:** The rate at which water passes a given point in a stream, usually expressed in cubic ft per second (cfs).

**Surplus:** Energy generated that is beyond the immediate needs of the producing system. This energy may be sold on an interruptible basis or as nonfirm power.

**Tailwater:** Water immediately below the power plant. Tailwater elevation refers to the level of that water.

**Thermal power plant:** Generating plant that converts heat energy into electrical energy. Coal, oil, and gas-fired power plants and nuclear power plants are common thermal resources.

**Thermal Resource:** Electrical generating means that rely on conventional fuels such as coal, oil, and gas.

**Transmission:** Transporting electric energy in bulk from one point to another in the power system rather than to individual customers.

**Transmission grid:** An inter-connected system of electric transmission lines and associated equipment for transferring electric energy in bulk.

**Turbine:** Machinery that converts kinetic energy of a moving fluid, such as falling water or steam, to mechanical power. Turbines are used to turn generators that convert mechanical energy to electricity.

**Usable storage:** Water occupying active storage capacity of a reservoir.

**Usable storage capacity:** The portion of the reservoir storage capacity in which water normally is stored, or from which water is withdrawn for beneficial uses, in compliance with operating agreements.

**Variable energy content curve (VECC):** The January through July portion of the energy content curve. The VECC is based on the expected amount of spring runoff.

**Water Budget:** A volume of water to be reserved and released in the spring if needed to assist in the downstream migration of juvenile salmon and steelhead.

**Water Rights:** Priority claims to water. In western States, water rights are based on the principle "first in time, first in right," meaning older claims take precedence over newer ones.

**Watt:** A measure of the rate at which energy is produced, exchanged, or consumed.

**Wheeling:** Using transmission facilities of one system to transmit power of and for another system.

# Annex A

# Comparison Tables

Table A-1. Comparison of Key Data for Alternative A1 and Alternative A2

| Key Data | **Alternative A1** | **Alternative A2** | **Difference A1 – A2** |
|---|---|---|---|
| Brownlee Reservoir | | | |
| July Average-EOM Elev. – ft | 2,069.0 | 2,069.0 | 0 |
| July's did not refill – No. | 60 | 60 | 0 |
| Average Pool Elev. - ft | 2,059.3 | 2,059.3 | 0 |
| | | | |
| Dworshak Reservoir | | | |
| July Average EOM Elev. – ft | 1,563.6 | 1,563.6 | 0 |
| July's did not refill – No. | 42 | 41 | 1 |
| Average Pool Elev. - ft | 1,539.6 | 1,539.6 | 0 |
| | | | |
| Lower Granite | | | |
| Apr 2- Jun 60-year Average Regulated Flow – cfs | 103,937 | 103.938 | -1 |
| Jul – Aug 2 60-year Average Regulated Flow – cfs | 42,236 | 42,239 | -3 |
| | | | |
| McNary Project | | | |
| Apr 2- Jun 60-year Average Regulated Flow – cfs | 269,654 | 269,488 | 166 |
| Jul – Aug 2 60-year Average Regulated Flow – cfs | 165,424 | 165,532 | 108 |
| | | | |
| Average System Generation | 14,038 | 14,108 | -70 |
| | | | |

Table A-2. Comparison of Key Data for Alternative A1 and Alternative A3

| Key Data | Alternative A1 | Alternative A3 | Difference A1 – A3 |
|---|---|---|---|
| Brownlee Reservoir | | | |
| July Average EOM Elev. – ft | 2,069.0 | 2,069.0 | 0 |
| July's did not refill – No. | 60 | 60 | 0 |
| Average Pool Elev. - ft | 2,059.3 | 2,059.3 | 0 |
| | | | |
| Dworshak Reservoir | | | |
| July Average EOM Elev. – ft | 1,563.6 | 1,561.0 | 2.6 |
| July's did not refill – No. | 42 | 46 | -4 |
| Average Pool Elev. - ft | 1,539.6 | 1,538.3 | 1.3 |
| | | | |
| Lower Granite | | | |
| Apr 2- Jun 60-year Average Regulated Flow – cfs | 103,937 | 103,967 | -30 |
| Jul – Aug 2 60-year Average Regulated Flow – cfs | 42,236 | 42,410 | -174 |
| | | | |
| McNary Project | | | |
| Apr 2- Jun 60-year Average Regulated Flow – cfs | 269,654 | 268,698 | 956 |
| Jul – Aug 2 60-year Average Regulated Flow – cfs | 165,424 | 166,860 | -1,436 |
| | | | |
| Average System Generation | 14,038 | 12,771 | -1,267 |
| | | | |

Table A-3. Comparison of Key Data for Alternative A1 and Alternative A5

| Key Data | Alternative A1 | Alternative A5 | Difference A1 – A5 |
|---|---|---|---|
| Brownlee Reservoir | | | |
| July Average EOM Elev. – ft | 2,069.0 | 2,072.0 | -3 |
| July's did not refill – No. | 60 | 46 | 14 |
| Average Pool Elev. - ft | 2,059.3 | 2,060.3 | 1.0 |
| | | | |
| Dworshak Reservoir | | | |
| July Average EOM Elev. – ft | 1,563.6 | 1,592.3 | -28.70 |
| July's did not refill – No. | 42 | 42 | 0 |
| Average Pool Elev. - ft | 1,539.6 | 1,528.7 | 10.7 |
| | | | |
| Lower Granite | | | |
| Apr 2- Jun 60-year Average Regulated Flow – cfs | 103,937 | 98,104 | 5,833 |
| Jul – Aug 2 60-year Average Regulated Flow – cfs | 42,236 | 37,681 | 4,555 |
| | | | |
| McNary Project | | | |
| Apr 2- Jun 60-year Average Regulated Flow – cfs | 269,654 | 263,151 | 6,503 |
| Jul – Aug 2 60-year Average Regulated Flow – cfs | 165,424 | 156,512 | 8,912 |
| | | | |
| Average System Generation | 14,038 | 12,805 | 1,233 |
| | | | |

Table A-4. Comparison of Key Data for Alternative A1 and Alternative A6a

| Key Data | **Alternative A1** | **Alternative A6a** | **Difference A1 – A6a** |
|---|---|---|---|
| Brownlee Reservoir | | | |
| July Average EOM Elev. – ft | 2,069.0 | 2,069.0 | 0 |
| July's did not refill – No. | 60 | 60 | 0 |
| Average Pool Elev. – ft | 2,059.3 | 2,058.2 | 1.10 |
| | | | |
| Dworshak Reservoir | | | |
| July Average EOM Elev. – ft | 1,563.6 | 1,569.6 | -6 |
| July's did not refill – No. | 42 | 47 | -5 |
| Average Pool Elev. – ft | 1,539.6 | 1,542.5 | -2.90 |
| | | | |
| Lower Granite | | | |
| Apr 2- Jun 60-year Average Regulated Flow – cfs | 103,937 | 104,800 | -863 |
| Jul – Aug 2 60-year Average Regulated Flow – cfs | 42,236 | 47,248 | -5012 |
| | | | |
| McNary Project | | | |
| Apr 2- Jun 60-year Average Regulated Flow – cfs | 269,654 | 271,020 | -1,366 |
| Jul – Aug 2 60-year Average Regulated Flow – cfs | 165,424 | 169,659 | -4,235 |
| | | | |
| Average System Generation | 14,038 | 14,064 | -26 |
| | | | |

Table A-5. Comparison of Key Data for Alternative A1 and Alternative A6b

| Key Data | Alternative A1 | Alternative A6B | Difference A1 – A6b |
|---|---|---|---|
| Brownlee Reservoir | | | |
| July Average EOM Elev. – ft | 2,069.0 | 2,069.0 | 0 |
| July's did not refill – No. | 60 | 60 | 0 |
| Average Pool Elev. – ft | 2,059.3 | 2,058.2 | 1.10 |
| | | | |
| Dworshak Reservoir | | | |
| July Average EOM Elev. – ft | 1,563.6 | 1,569.6 | -6 |
| July's did not refill – No. | 42 | 47 | -5 |
| Average Pool Elev. – ft | 1,539.6 | 1,542.5 | -2.90 |
| | | | |
| Lower Granite | | | |
| Apr 2- Jun 60-year Average Regulated Flow – cfs | 103,937 | 104,800 | -863 |
| Jul – Aug 2 60-year Average Regulated Flow – cfs | 42,236 | 47,248 | -5,012 |
| | | | |
| McNary Project | | | |
| Apr 2- Jun 60-year Average Regulated Flow – cfs | 269,654 | 271,020 | -1,366 |
| Jul – Aug 2 60-year Average Regulated Flow – cfs | 165,424 | 169,659 | -4,235 |
| | | | |
| Average System Generation | 14,038 | 14,028 | 10 |
| | | | |

Table A-6. Comparison of Key Data for Alternative A1 and Alternative B1

| Key Data | Alternative A1 | Alternative B1 | Difference A1 – B1 |
|---|---|---|---|
| Brownlee Reservoir | | | |
| July Average EOM Elev. – ft | 2,069.0 | 2,069.0 | 0 |
| July's did not refill – No. | 60 | 60 | 0 |
| Average Pool Elev. - ft | 2,059.3 | 2,059.3 | 0 |
| | | | |
| Dworshak Reservoir | | | |
| July Average EOM Elev. – ft | 1,563.6 | 1,561.4 | 2.2 |
| July's did not refill – No. | 42 | 46 | -4 |
| Average Pool Elev. - ft | 1,539.6 | 1,538.4 | 1.2 |
| | | | |
| Lower Granite | | | |
| Apr 2- Jun 60-year Average Regulated Flow – cfs | 103,937 | 103,934 | 3 |
| Jul – Aug 2 60-year Average Regulated Flow – cfs | 42,236 | 42,450 | -214 |
| | | | |
| McNary Project | | | |
| Apr 2- Jun 60-year Average Regulated Flow – cfs | 269,654 | 268,067 | 1,387 |
| Jul – Aug 2 60-year Average Regulated Flow – cfs | 165,424 | 167,111 | -1,687 |
| | | | |
| Average System Generation | 14,038 | 11,647 | 2,391 |
| | | | |

Table A-7. Comparison of Key Data for Alternative A1 and Alternative B2

| Key Data | Alternative A1 | Alternative B2 | Difference A1 – B2 |
|---|---|---|---|
| Brownlee Reservoir | | | |
| July Average EOM Elev. – ft | 2,069.0 | 2,072.0 | -3.0 |
| July's did not refill – No. | 60 | 46 | 14 |
| Average Pool Elev. – ft | 2,059.3 | 2,060.3 | -1.0 |
| | | | |
| Dworshak Reservoir | | | |
| July Average EOM Elev. – ft | 1,563.6 | 1,598.5 | -34.90 |
| July's did not refill – No. | 42 | 13 | 29 |
| Average Pool Elev. – ft | 1,539.6 | 1,544.1 | -4.50 |
| | | | |
| Lower Granite | | | |
| Apr 2- Jun 60-year Average Regulated Flow – cfs | 103,937 | 98,373 | 5,564 |
| Jul – Aug 2 60-year Average Regulated Flow – cfs | 42,236 | 31,865 | 10,371 |
| | | | |
| McNary Project | | | |
| Apr 2- Jun 60-year Average Regulated Flow – cfs | 269,654 | 254,346 | 15,308 |
| Jul – Aug 2 60-year Average Regulated Flow – cfs | 165,424 | 148,092 | 17,332 |
| | | | |
| Average System Generation | 14,038 | 11,734 | 2,304 |
| | | | |

Table A-8. Comparison of Key Data for Alternative A1 and Alternative C1

| Key Data | Alternative A1 | Alternative C1 | Difference A1 – C1 |
|---|---|---|---|
| Brownlee Reservoir | | | |
| July Average EOM Elev. – ft | 2,069.0 | 2,069.0 | 0 |
| July's did not refill – No. | 60 | 60 | 0 |
| Average Pool Elev. - ft | 2,059.3 | 2,059.5 | -0.2 |
| | | | |
| Dworshak Reservoir | | | |
| July Average EOM Elev. – ft | 1,563.6 | 1,561.4 | 2.2 |
| July's did not refill – No. | 42 | 46 | -4 |
| Average Pool Elev. - ft | 1,539.6 | 1,538.3 | 1.3 |
| | | | |
| Lower Granite | | | |
| Apr 2- Jun 60-year Average Regulated Flow – cfs | 103,937 | 103,948 | 11 |
| Jul – Aug 2 60-year Average Regulated Flow – cfs | 42,236 | 42,432 | -196 |
| | | | |
| McNary Project | | | |
| Apr 2- Jun 60-year Average Regulated Flow – cfs | 269,654 | 268,586 | 1,068 |
| Jul – Aug 2 60-year Average Regulated Flow – cfs | 165,424 | 167,067 | -1,643 |
| | | | |
| Average System Generation | 14,038 | 12,206 | 1,832 |
| | | | |

Table A-9 Comparison of Key Data for Alternative A1 and Alternative C2

| Key Data | **Alternative A1** | **Alternative C2** | **Difference A1 – C2** |
|---|---|---|---|
| Brownlee Reservoir | | | |
| July Average EOM Elev. – ft | 2,069.0 | 2,072.0 | -3 |
| July's did not refill – No. | 60 | 46 | 14 |
| Average Pool Elev. - ft | 2,059.3 | 2,060.3 | -1.0 |
| | | | |
| Dworshak Reservoir | | | |
| July Average EOM Elev. – ft | 1,563.6 | 1,595.9 | -32.30 |
| July's did not refill – No. | 42 | 48 | -6 |
| Average Pool Elev. - ft | 1,539.6 | 1,544.1 | -4.5 |
| | | | |
| Lower Granite | | | |
| Apr 2- Jun 60-year Average Regulated Flow – cfs | 103,937 | 98,336 | 5,601 |
| Jul – Aug 2 60-year Average Regulated Flow – cfs | 42,236 | 31,935 | 10,301 |
| | | | |
| McNary Project | | | |
| Apr 2- Jun 60-year Average Regulated Flow – cfs | 269,654 | 251,625 | 18,029 |
| Jul – Aug 2 60-year Average Regulated Flow – cfs | 165,424 | 149,228 | 15,196 |
| | | | |
| Average System Generation | 14,038 | 12,276 | 1,762 |
| | | | |

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# Annex B

# Comparison Graphs

# Comparison Graphs

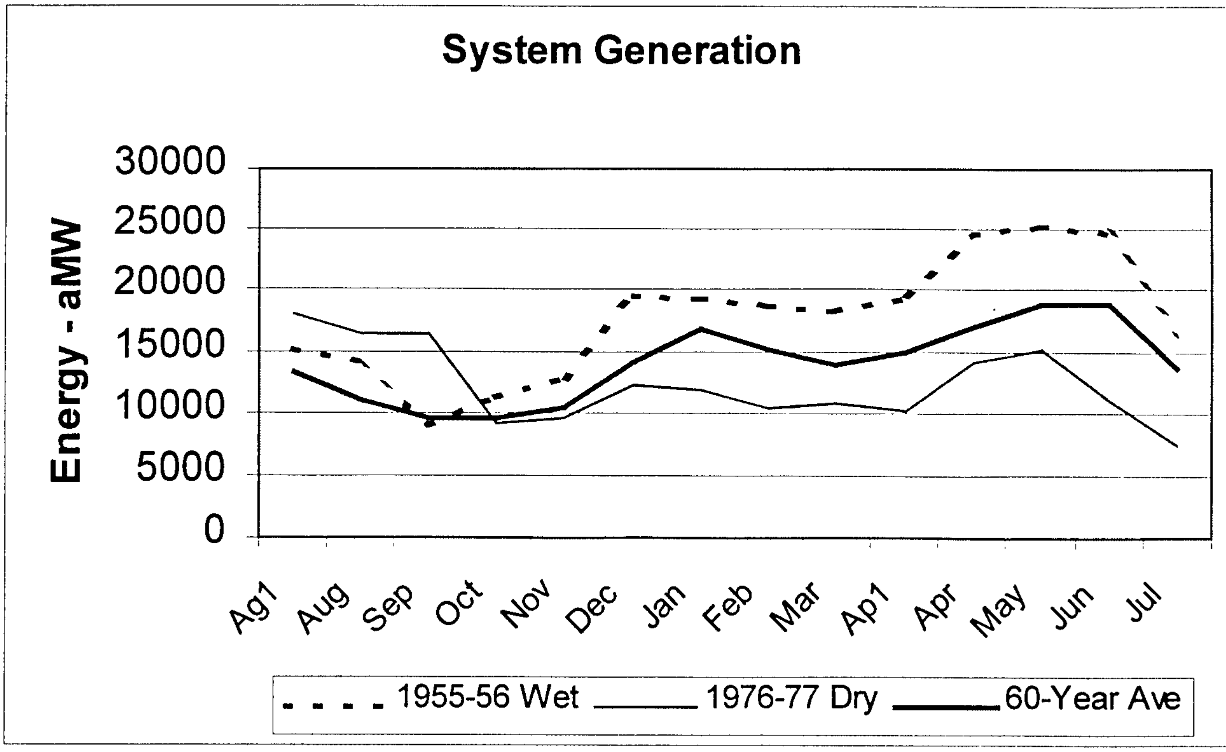
Hydroregulation data was graphed for each alternative at various points in the Columbia River Reservoir System. At Dworshak, the end-of-month elevation and regulated outflow was presented. A graph of the regulated outflow was provided for The Dalles, McNary, and Lower Granite. These graphs show a representative wet year that used 1955-56 water conditions, a representative dry year that used 1976-77 water conditions, and the 60-year average.

In order to show how each alternative impacted refill, a graph of probability of July refill was presented for Dworshak. The end of July data for the 60-year period of record was used to show the percent of time a given reservoir elevation was equaled or exceeded. For example, Figure B-1 shows Dworshak end of July reservoir elevation of 1,584 ft being equaled or exceeded 40 percent of the time.

During the spring anadromous migration season, the flows from April 16 through June 30 were averaged and used to develop a flow duration curve. Both Dworshak and Lower Granite were displayed. This graph can be used to determined the percent of time a given flow objective was equaled or exceeded. For example, Figure B-1 shows Dworshak regulated outflow of 8,987 cfs was equaled or exceeded 40 percent of the time.

The summer anadromous migration season flows from July 1 through August 31 were averaged and used to develop a flow duration curve. Both Dworshak and Lower Granite were displayed. This graph can be used to determined the percent of time a given flow objective was equaled or exceeded. For example, Figure B-1 shows Dworshak regulated outflow of 9,334 cfs was equaled or exceeded 40 percent of the time.

**Figure B-1. Alternative A1 Graphs**



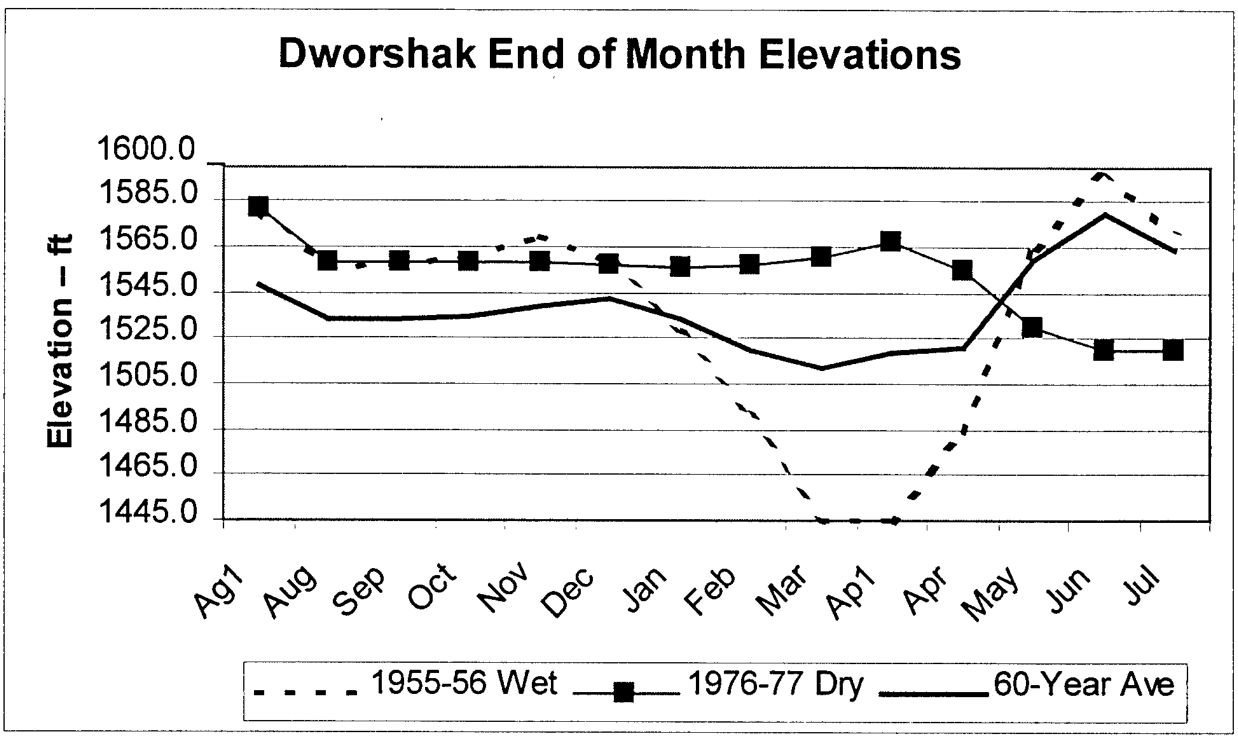
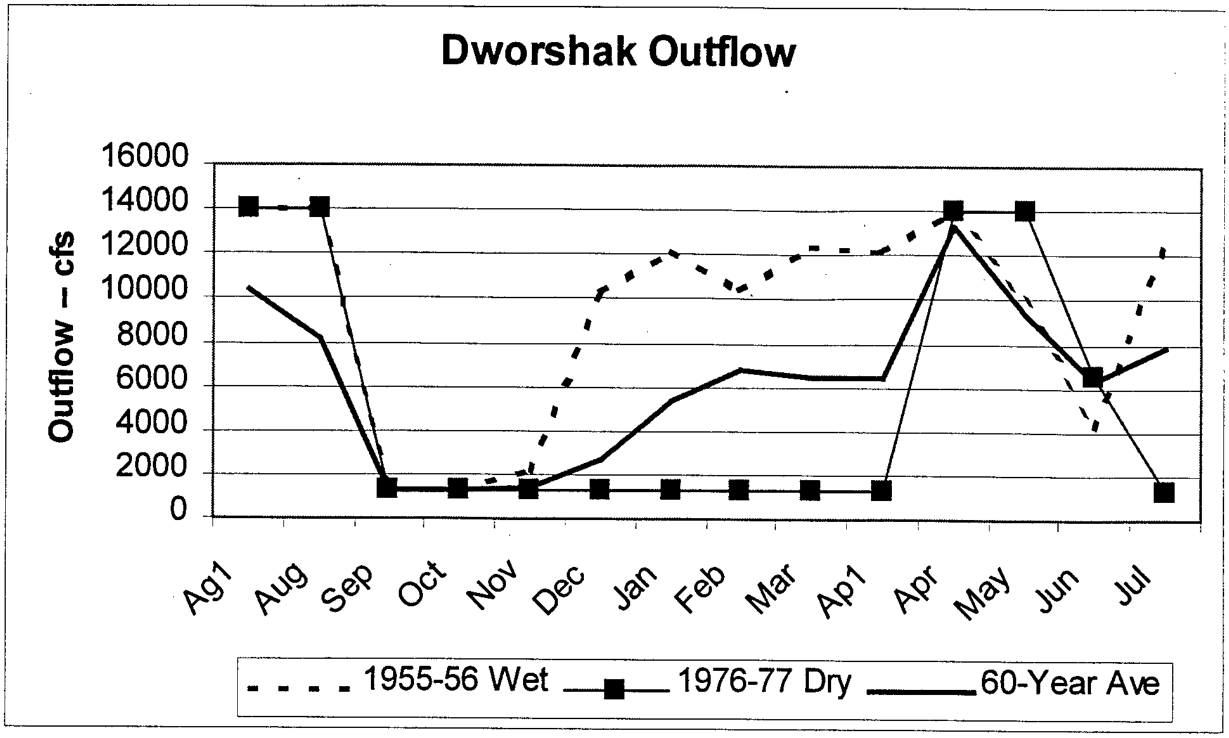



Figure B-1. Alternative A1 Graphs (continued)



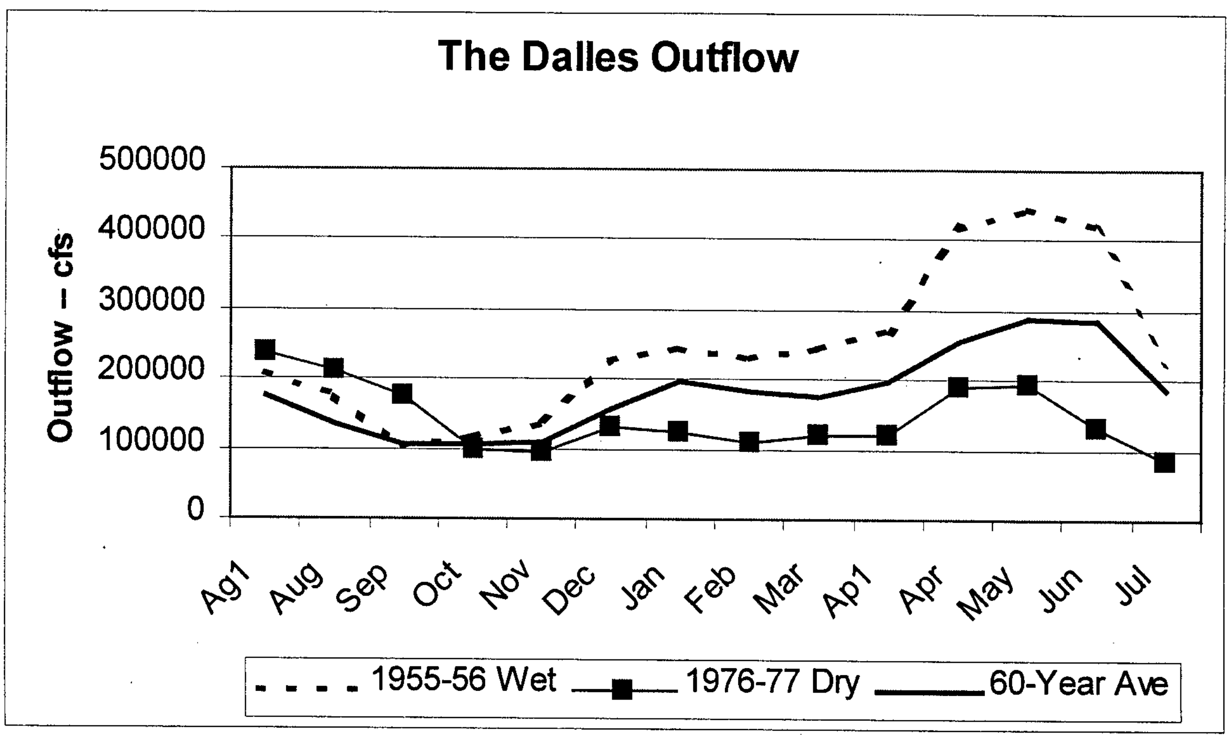
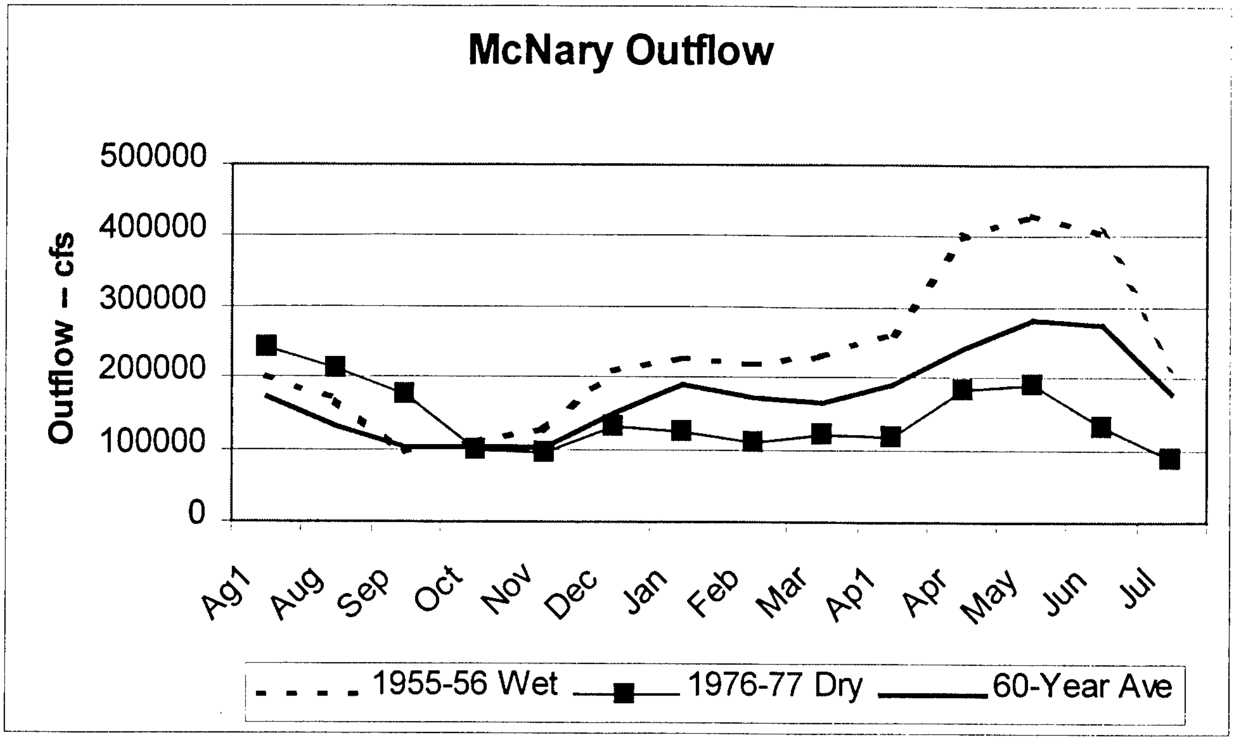



Figure B-1. Alternative A1 Graphs (continued)



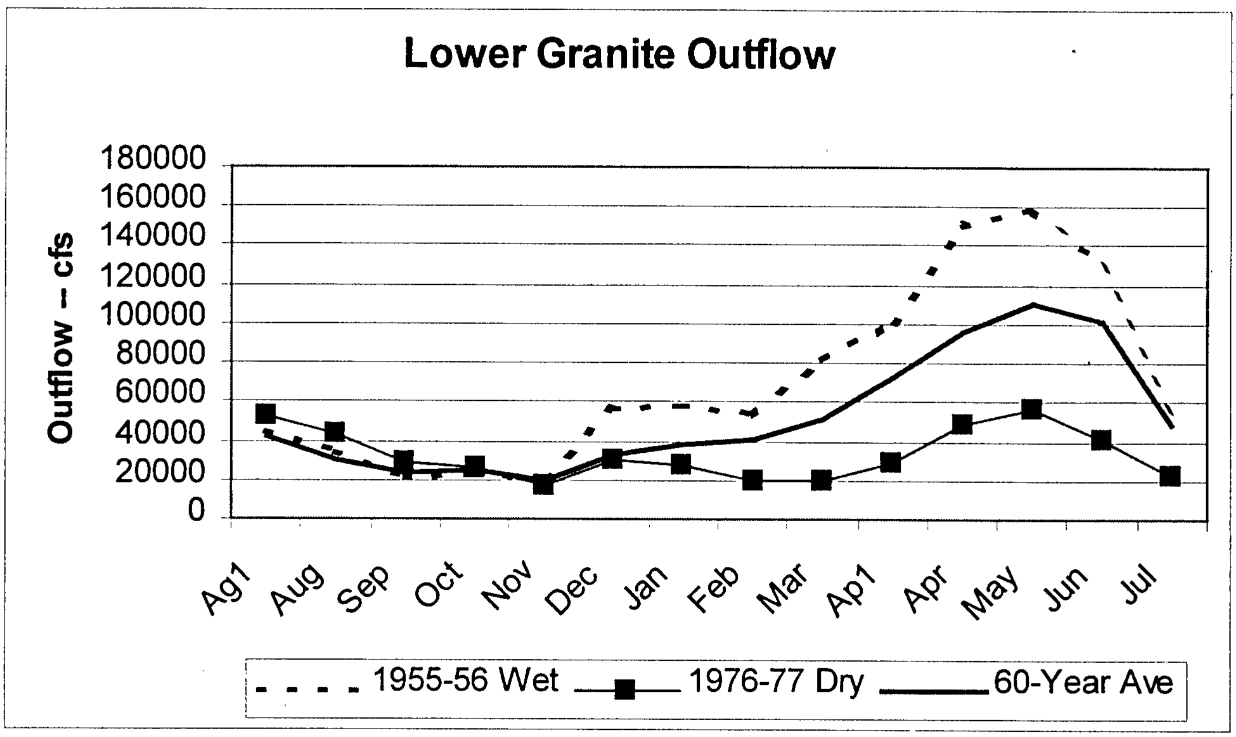
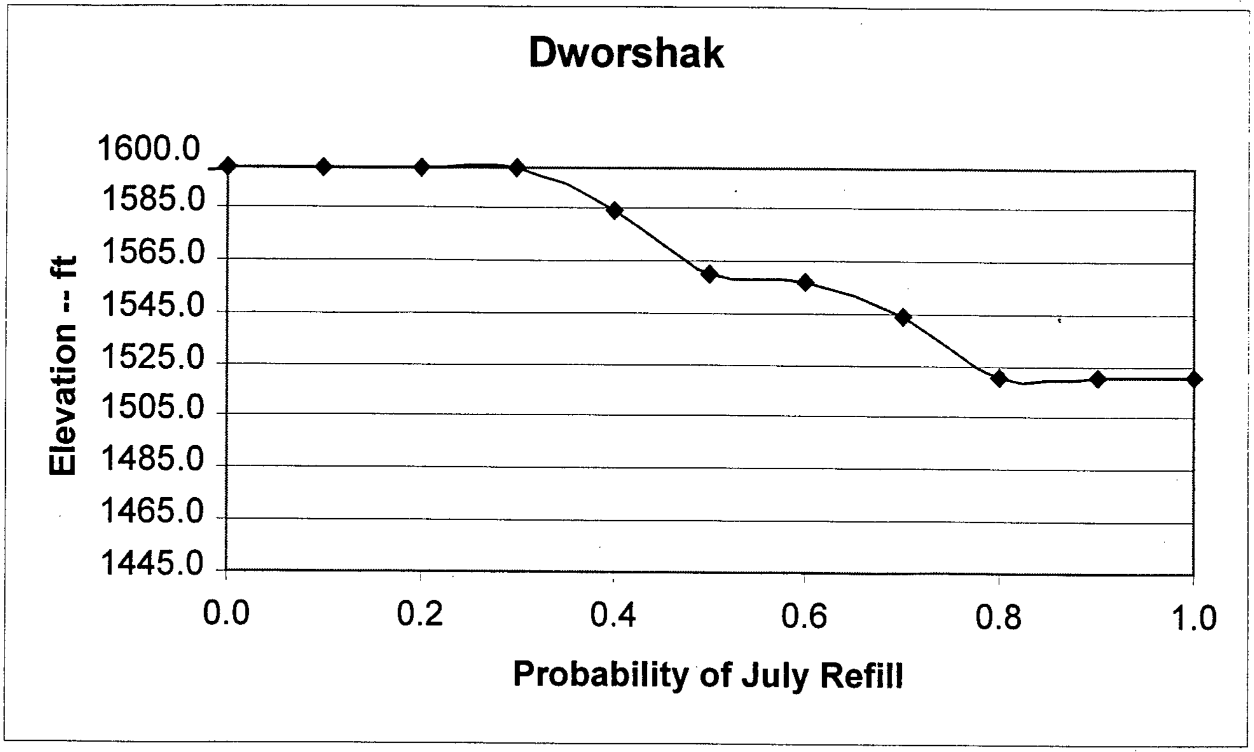



Figure B-1. Alternative A1 Graphs (continued)



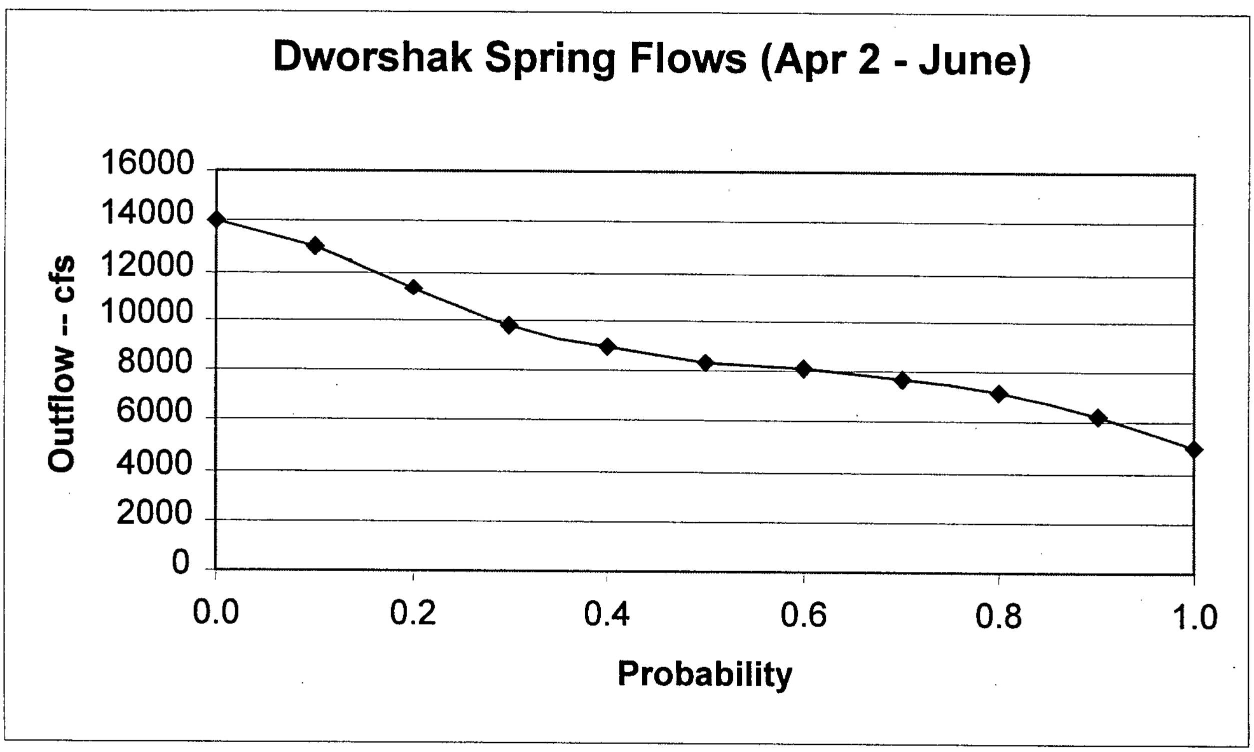
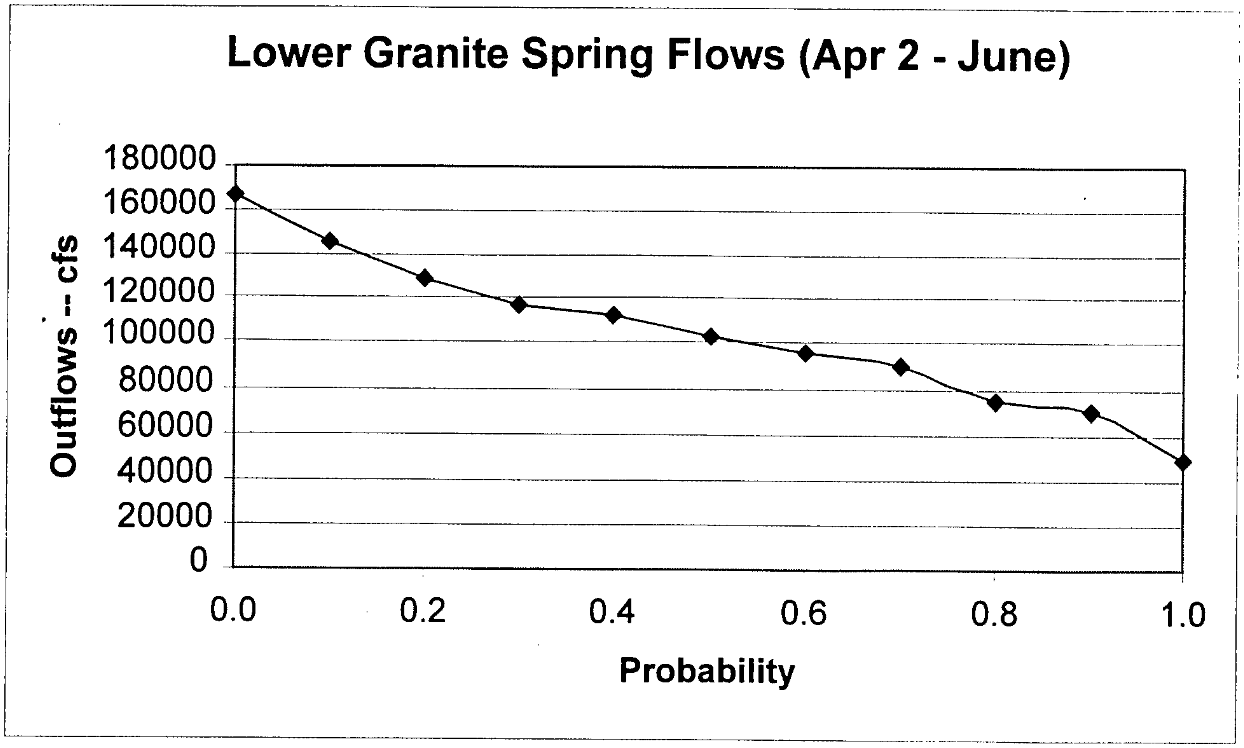



Figure B-1. Alternative A1 Graphs (continued)



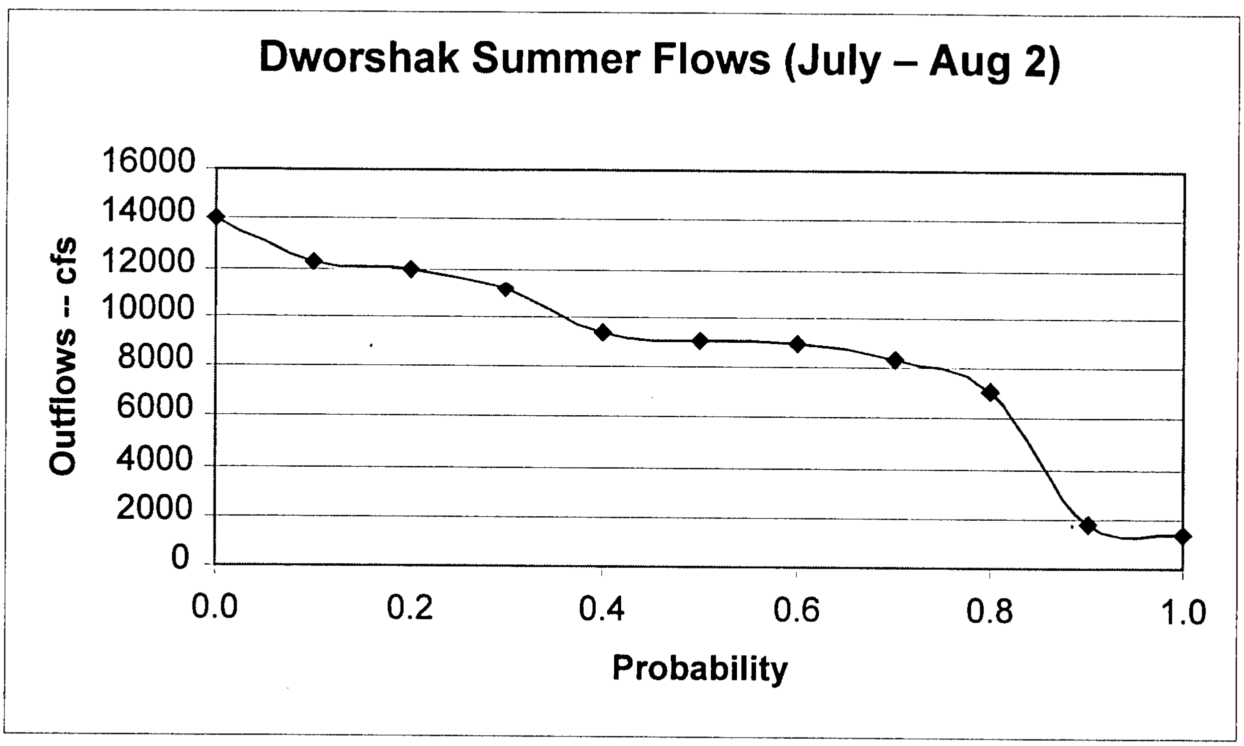



Figure B-1. Alternative A1 Graphs (continued)

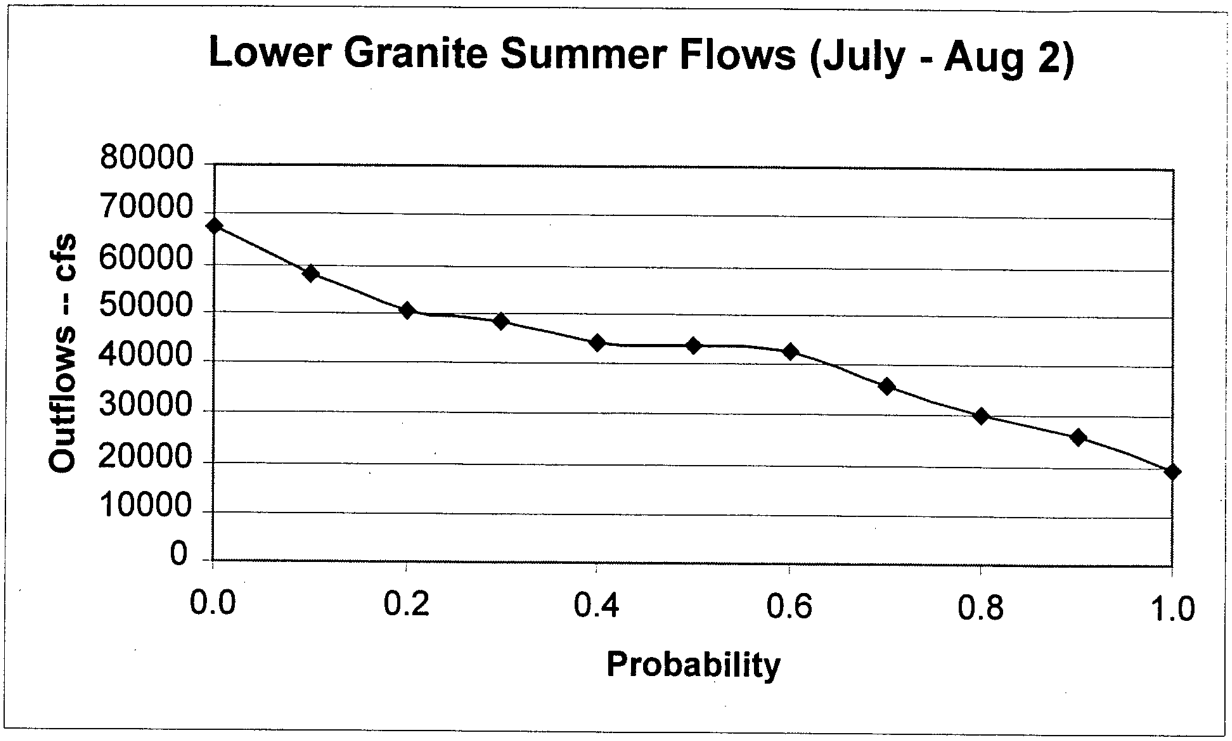
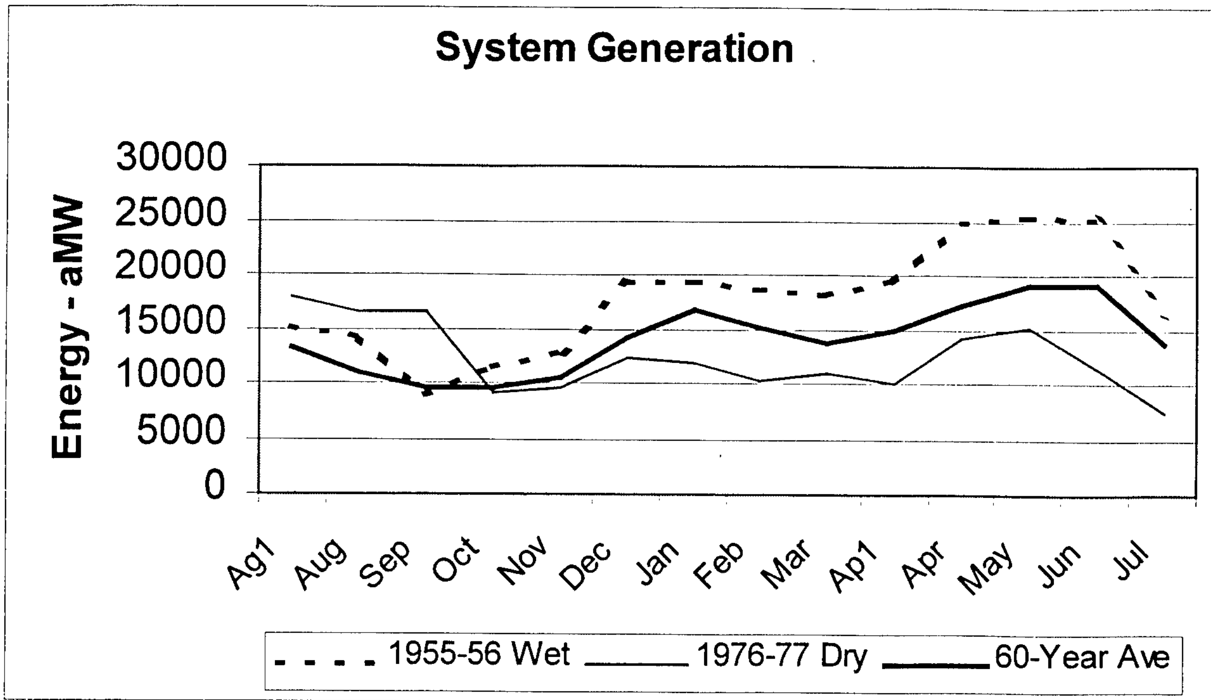
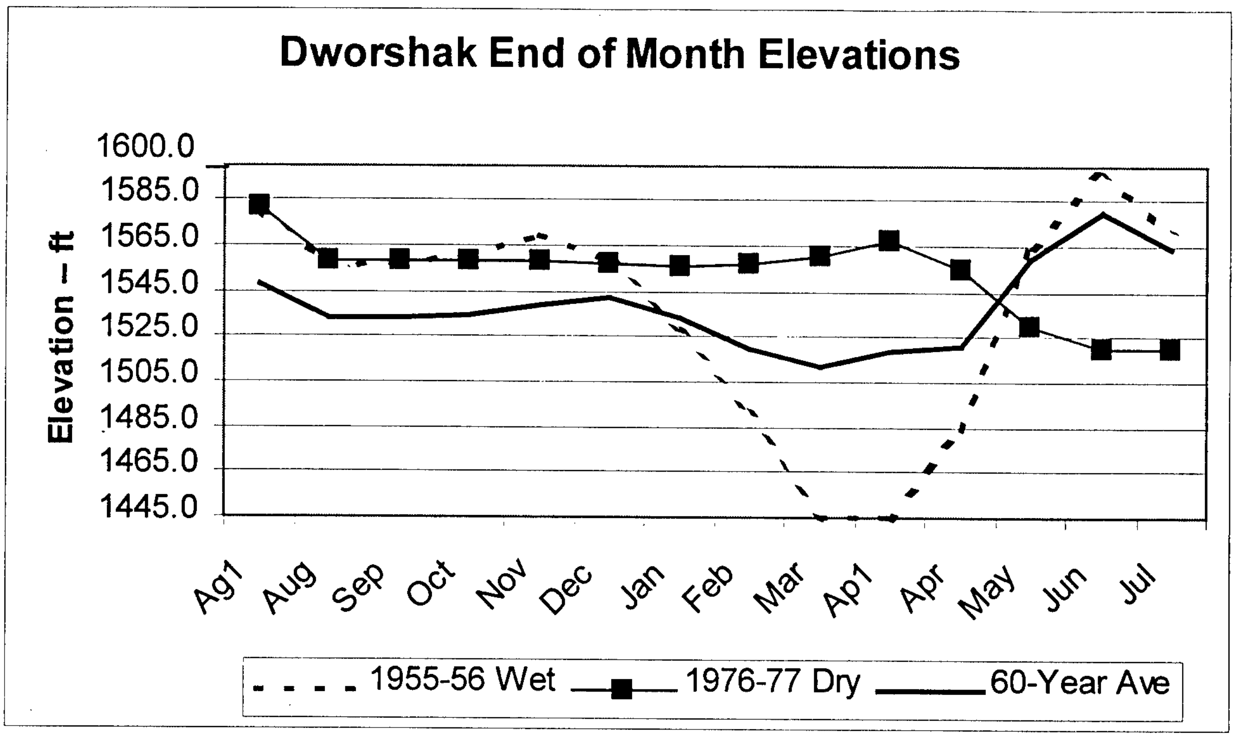


**Figure B-2. Alternative A2 Graphs**



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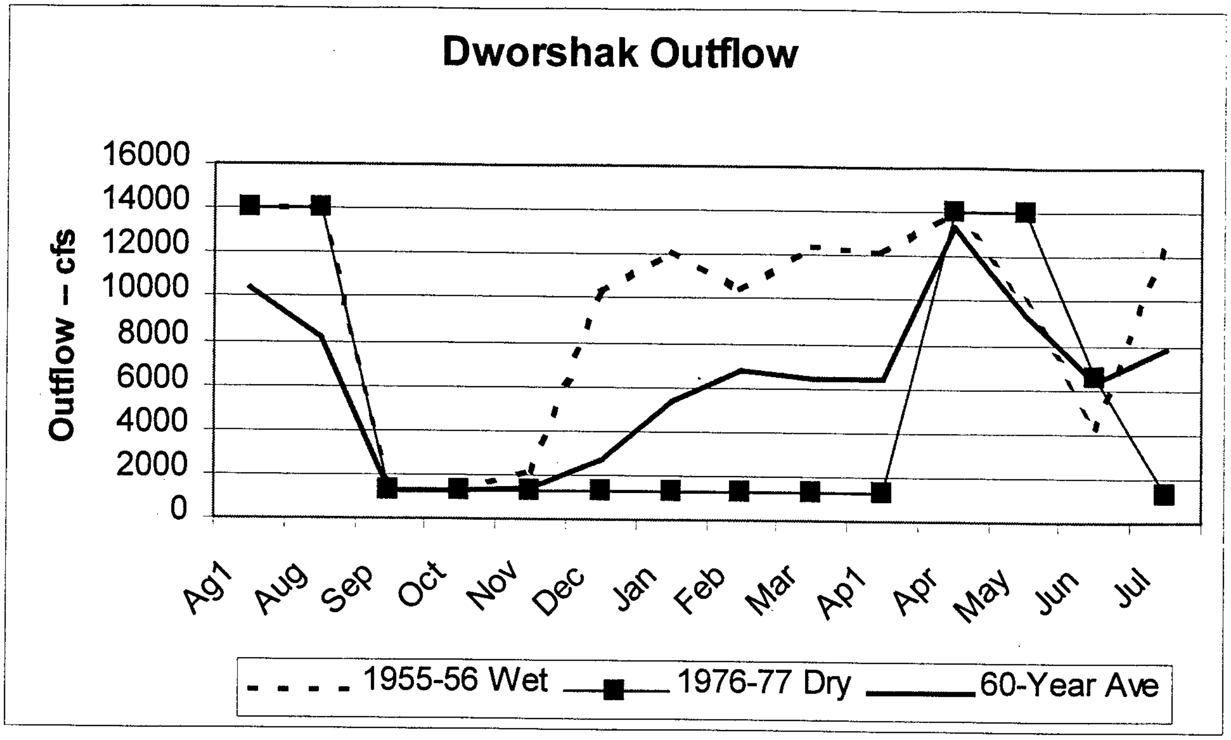


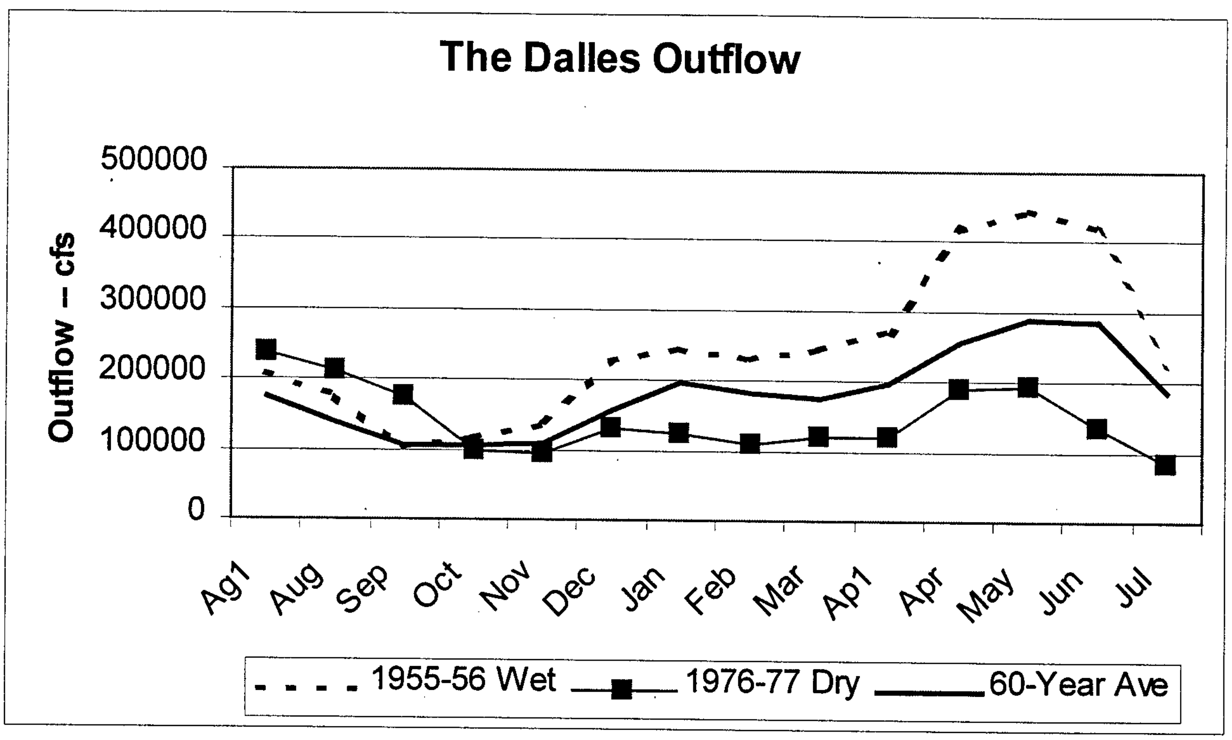
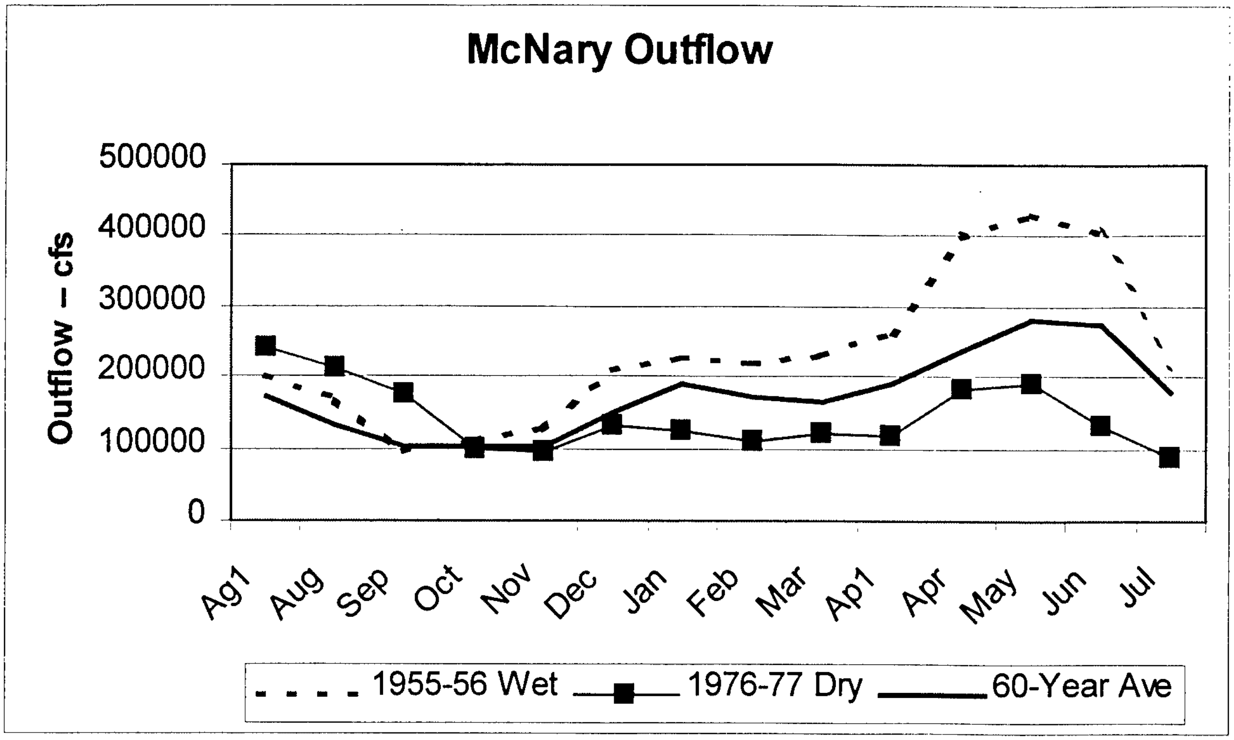



Figure B-2. Alternative A2 Graphs (continued)



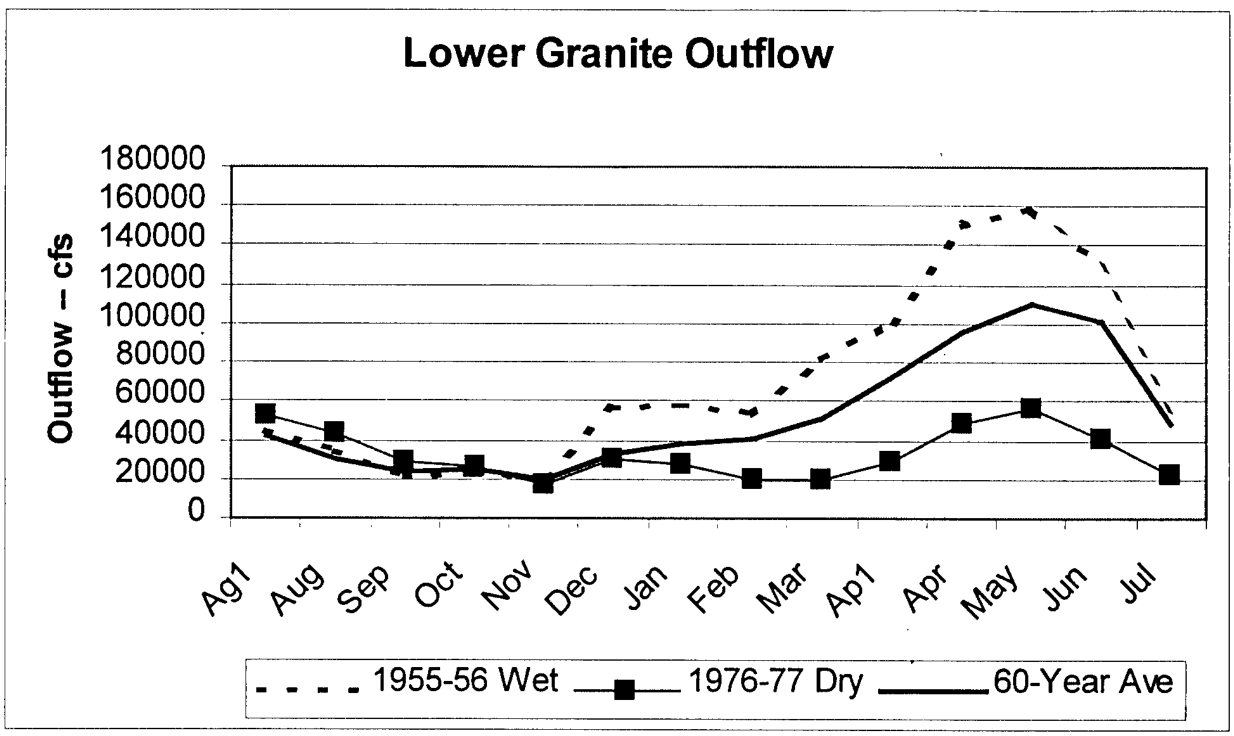
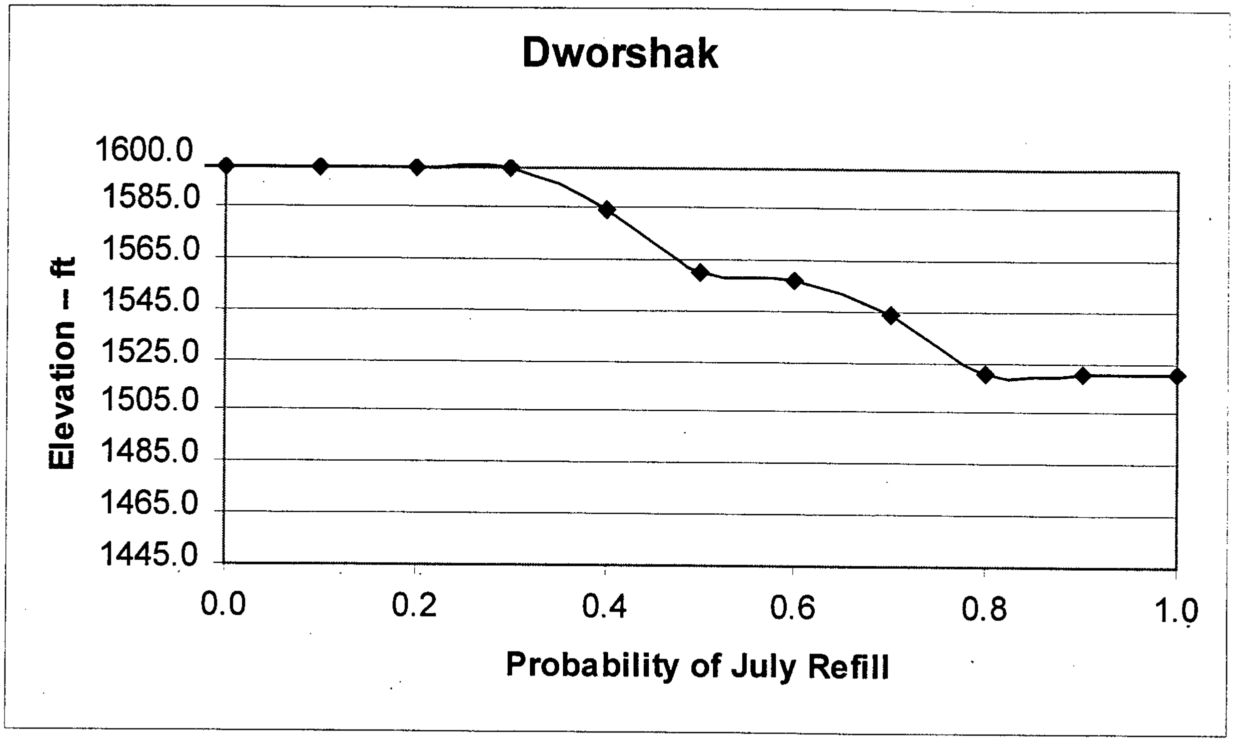
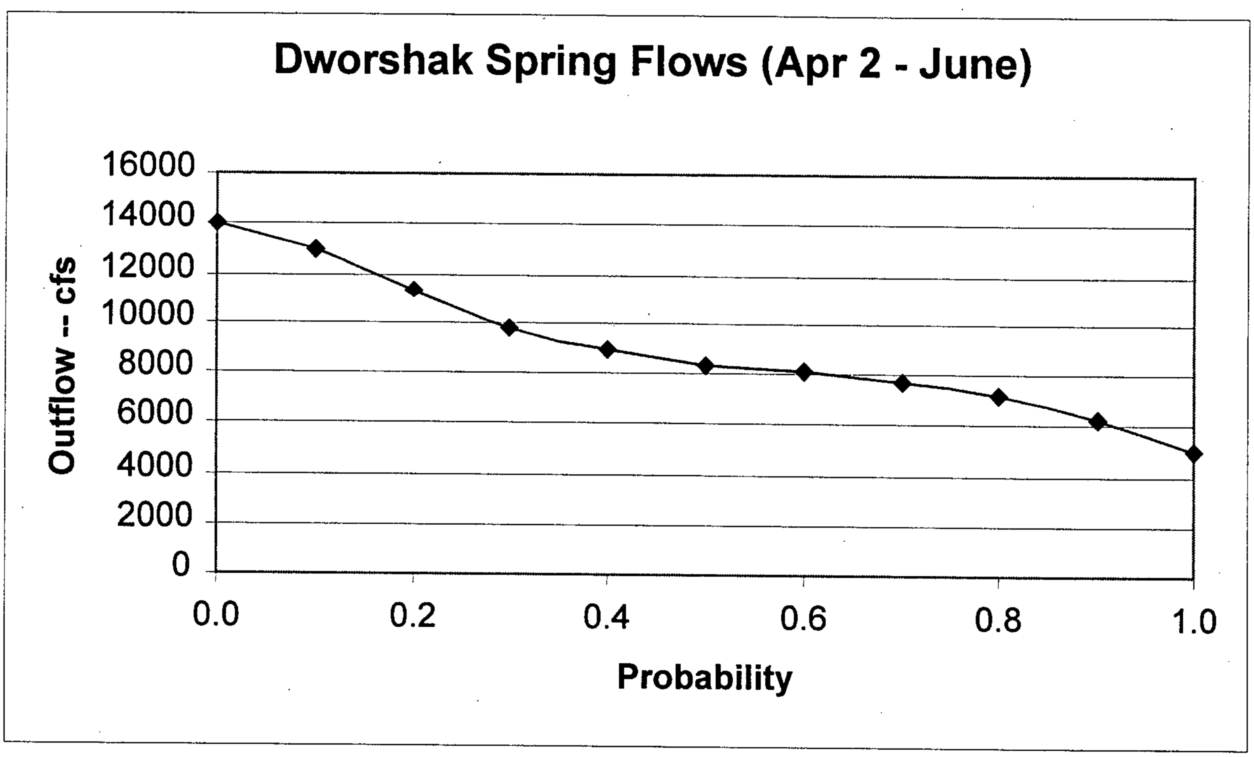



Figure B-2. Alternative A2 Graphs (continued)



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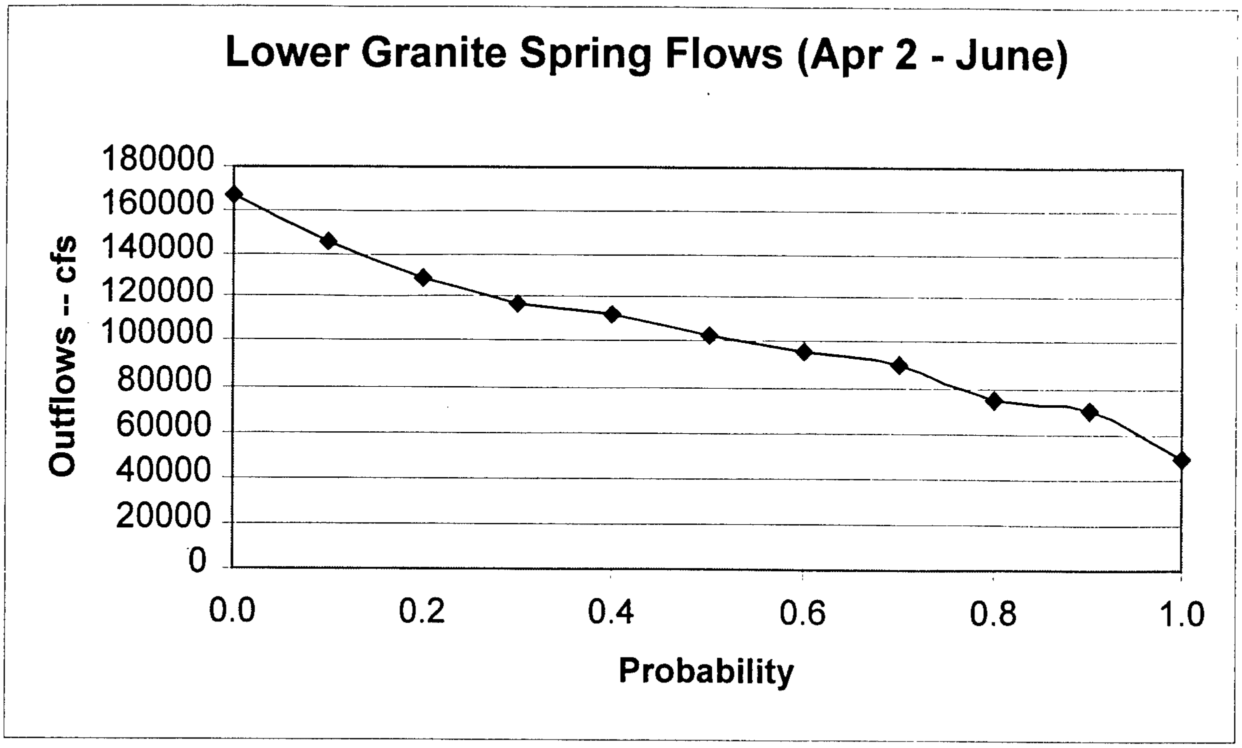


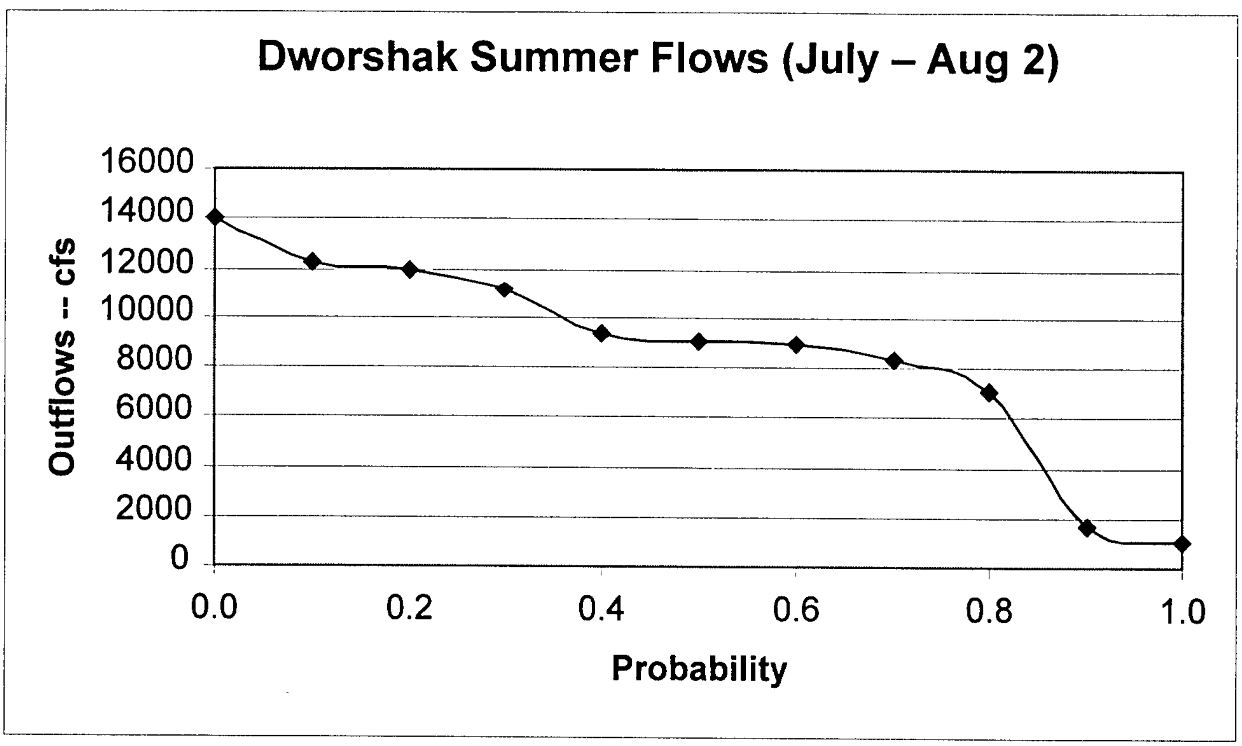



Figure B-2. Alternative A2 Graphs (continued)

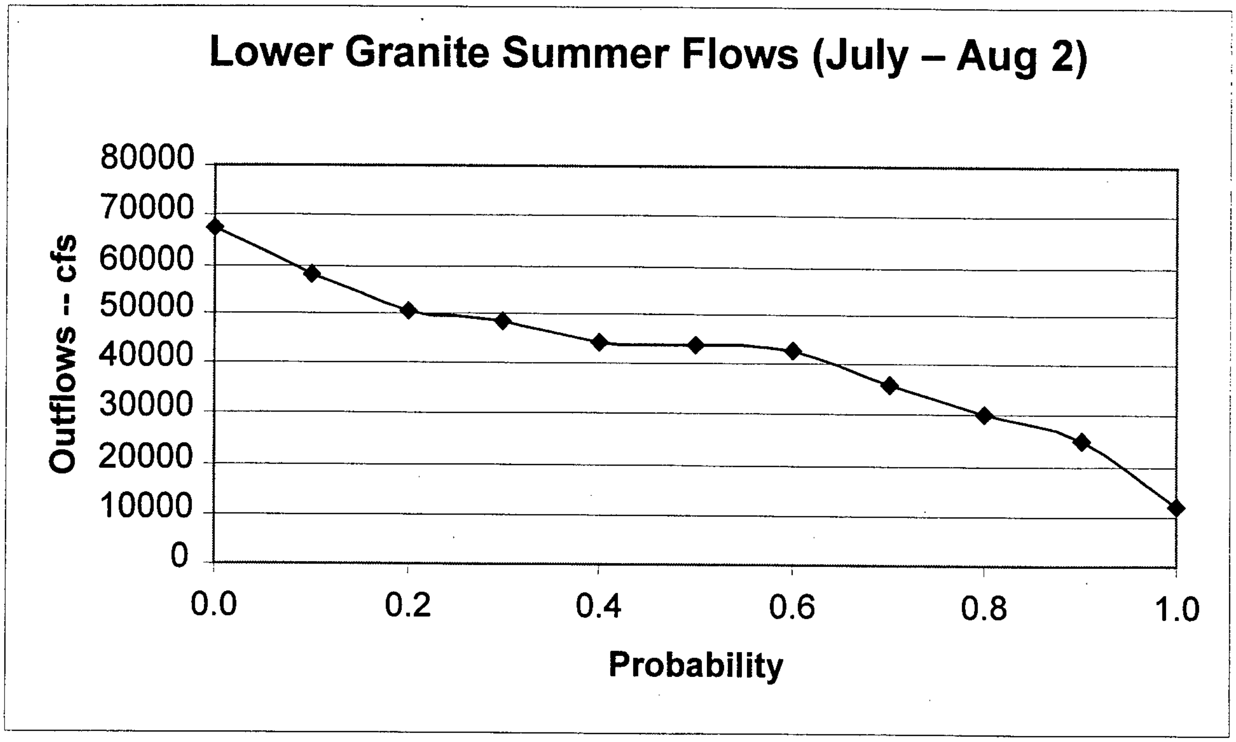
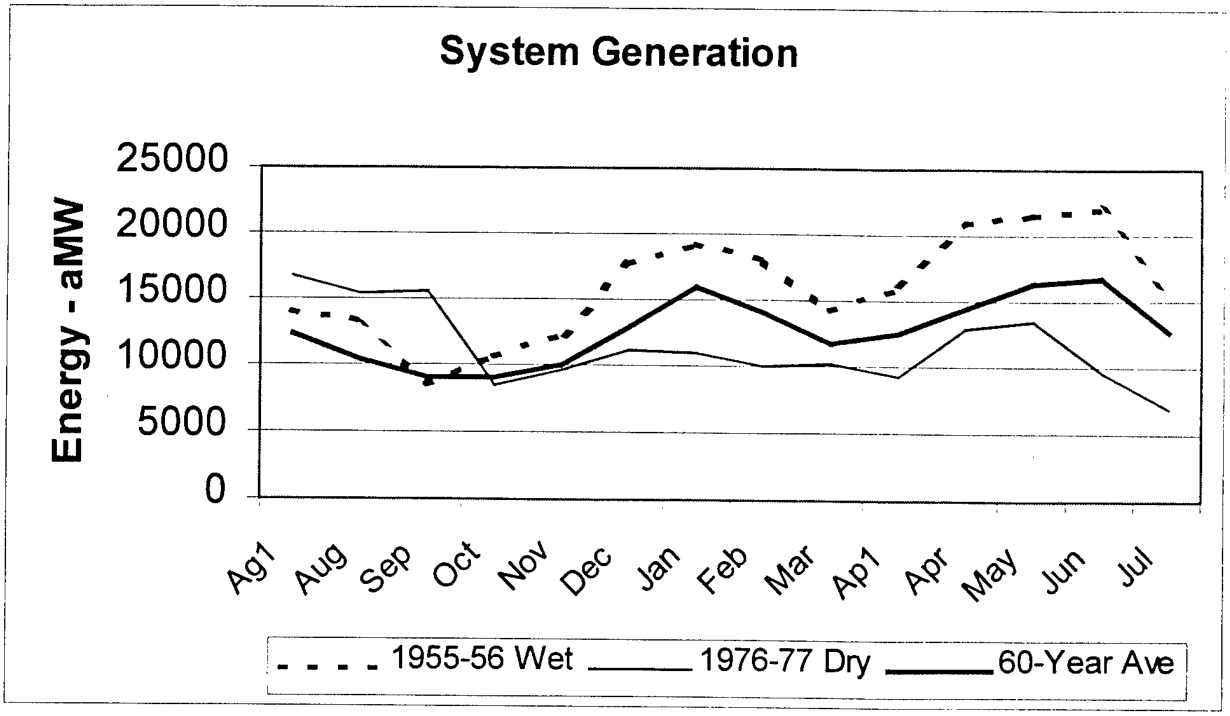


**Figure B-3. Alternative A3 Graphs**



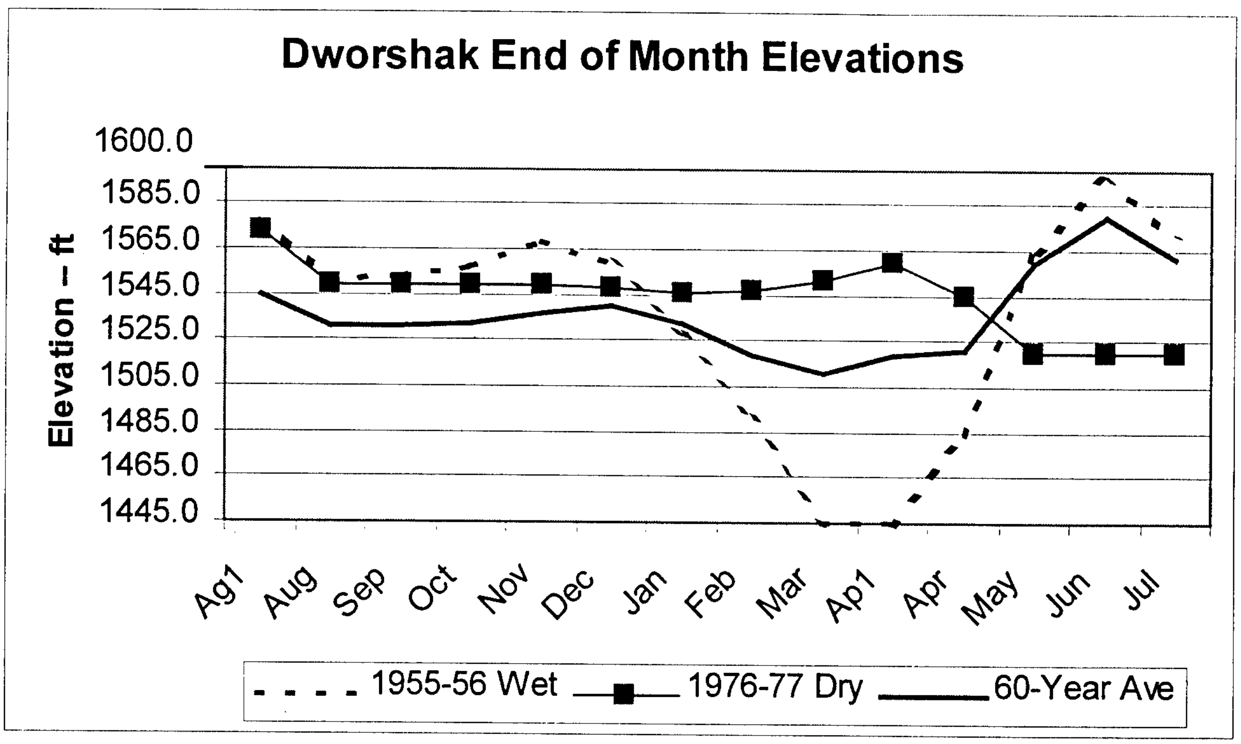
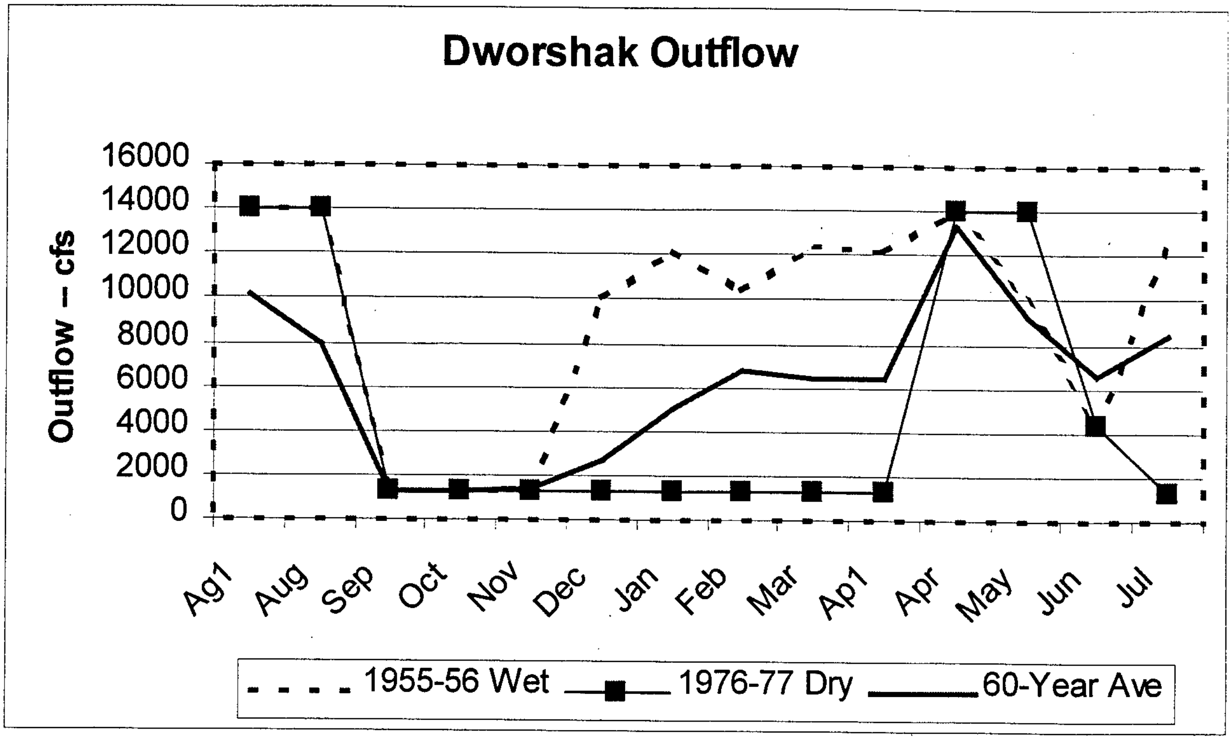



Figure B-3. Alternative A3 Graphs (continued)



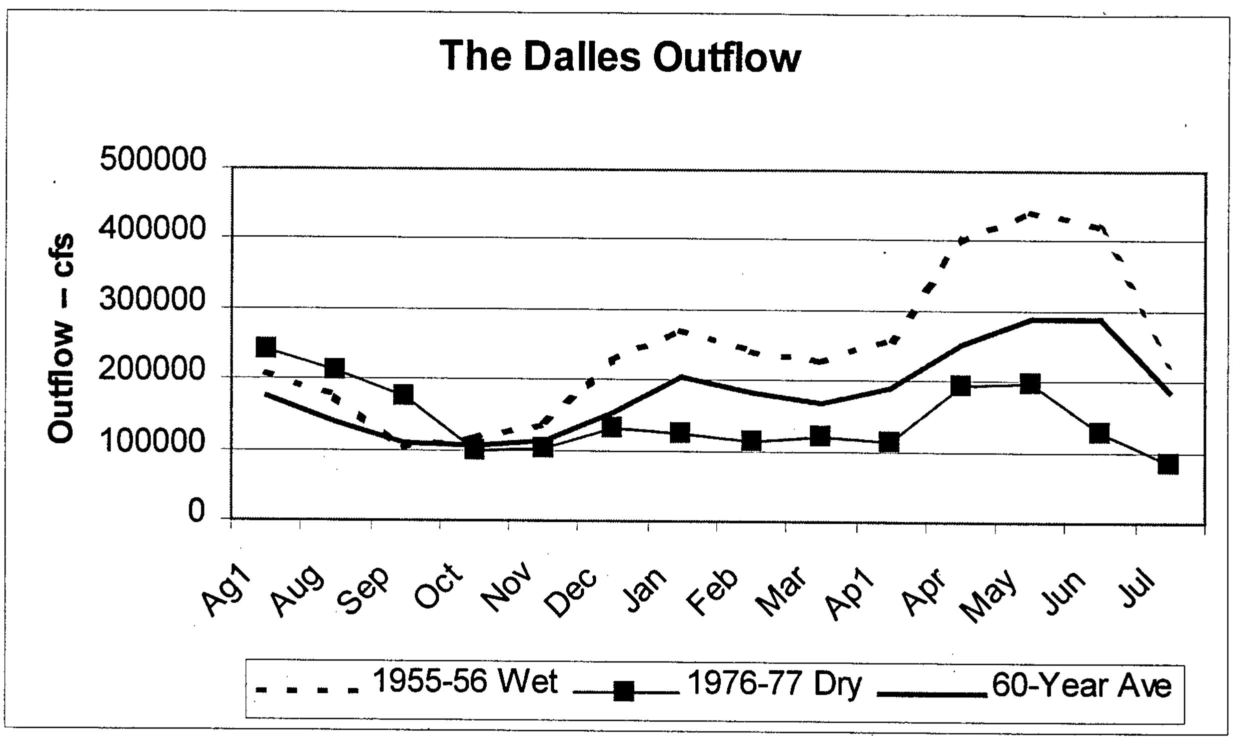
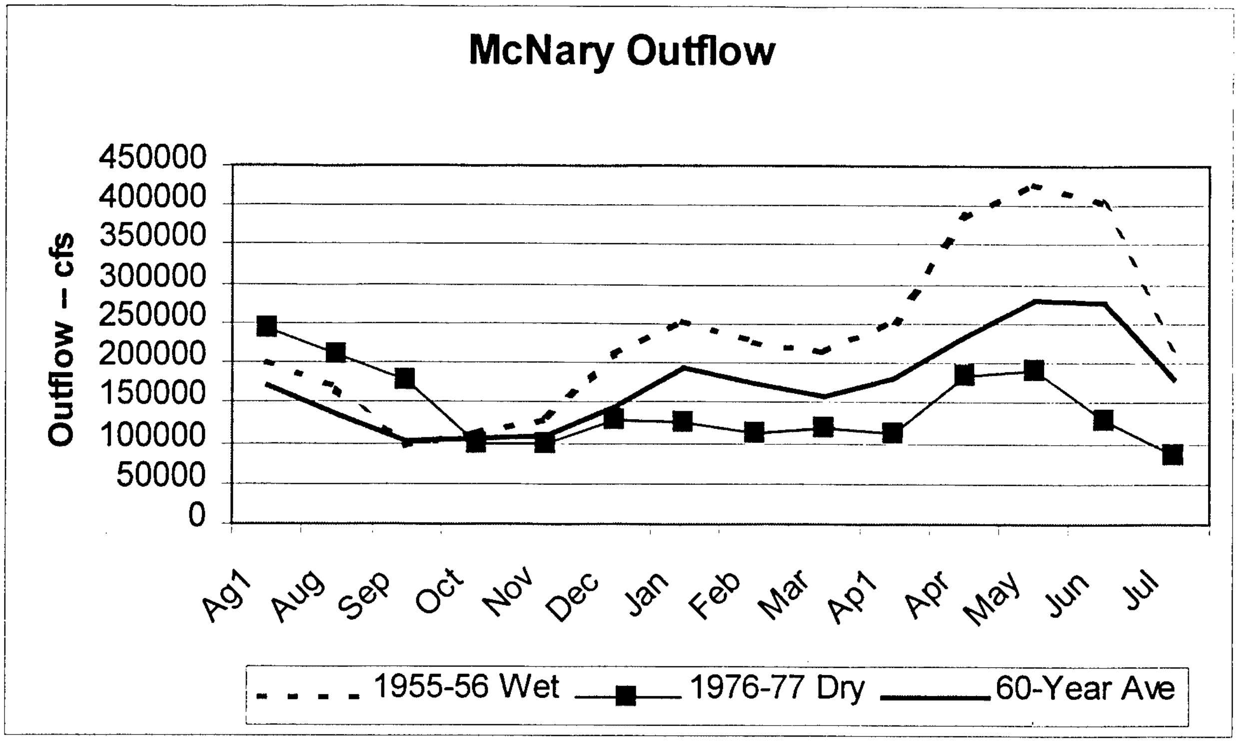



Figure B-4. Alternative A3 Graphs (continued)



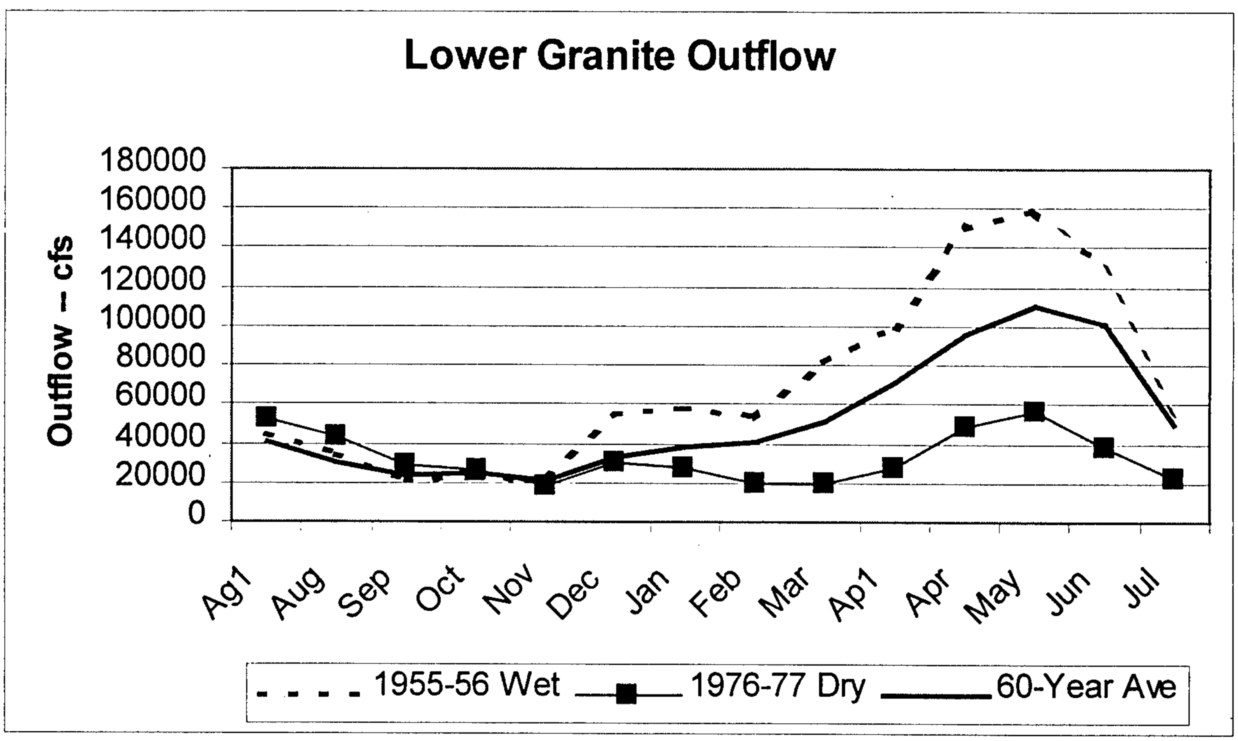
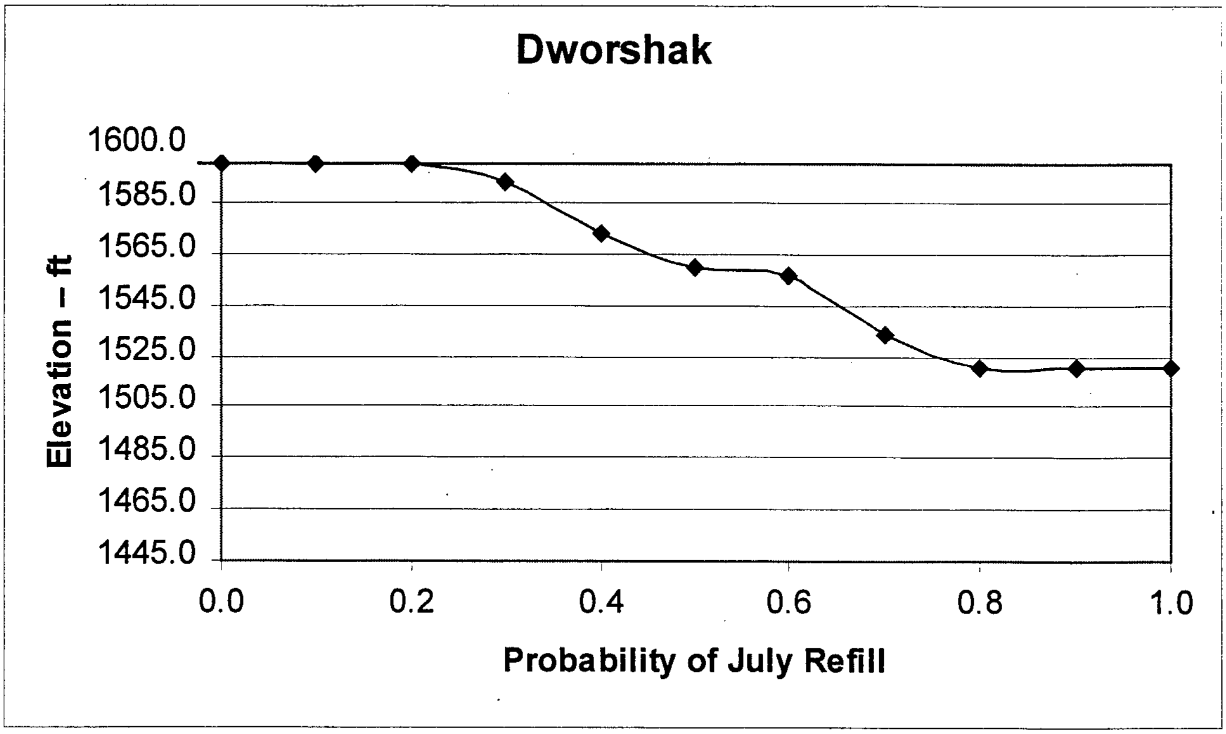



Figure B-4. Alternative A3 Graphs (continued)



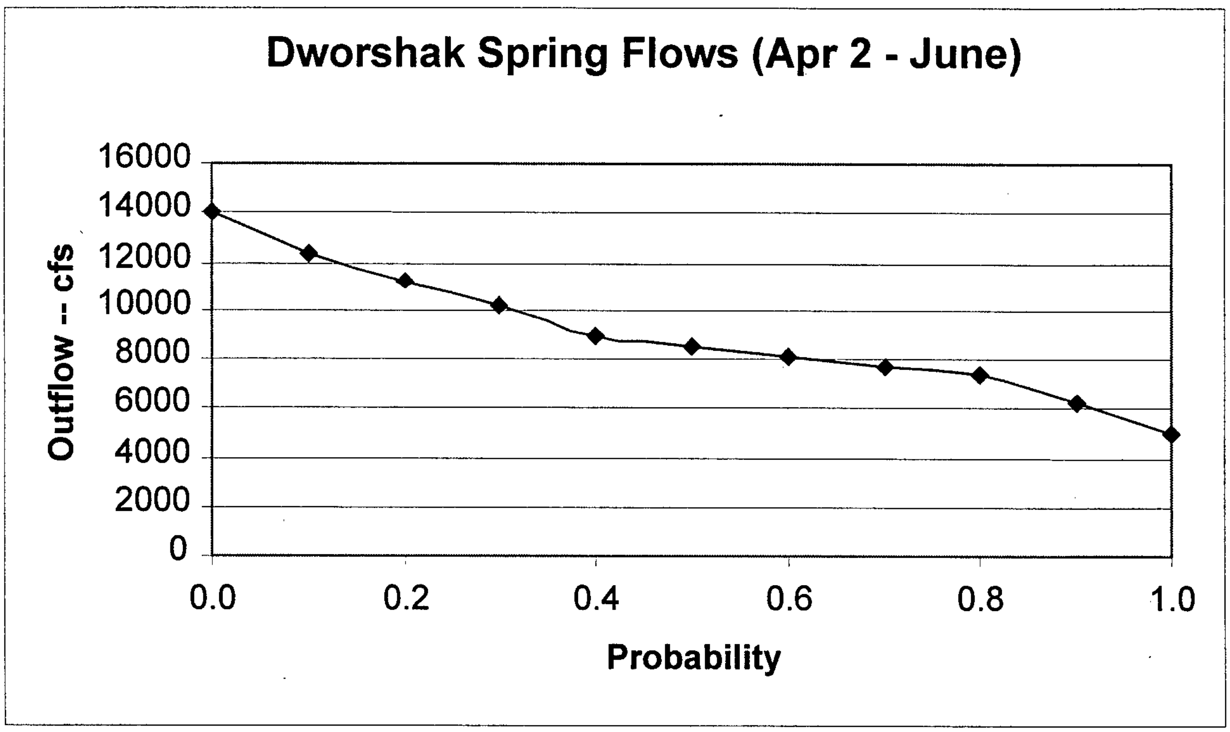
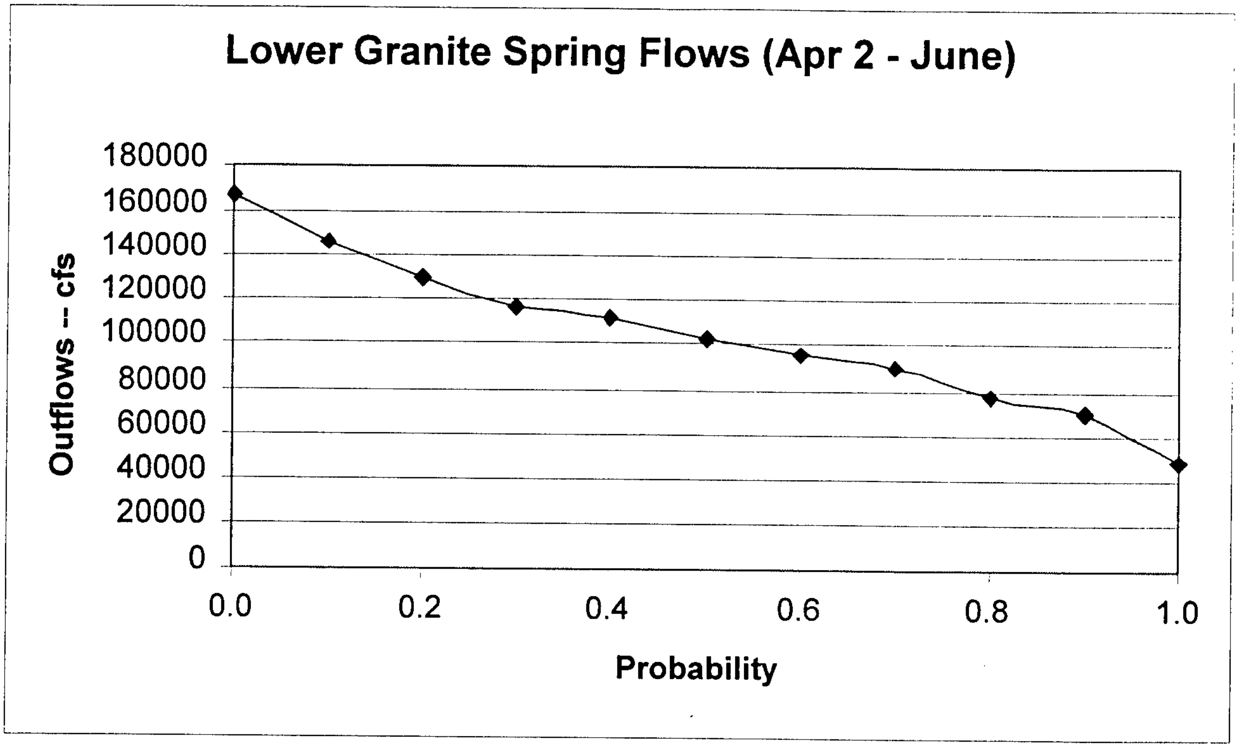



Figure B-4. Alternative A3 Graphs (continued)



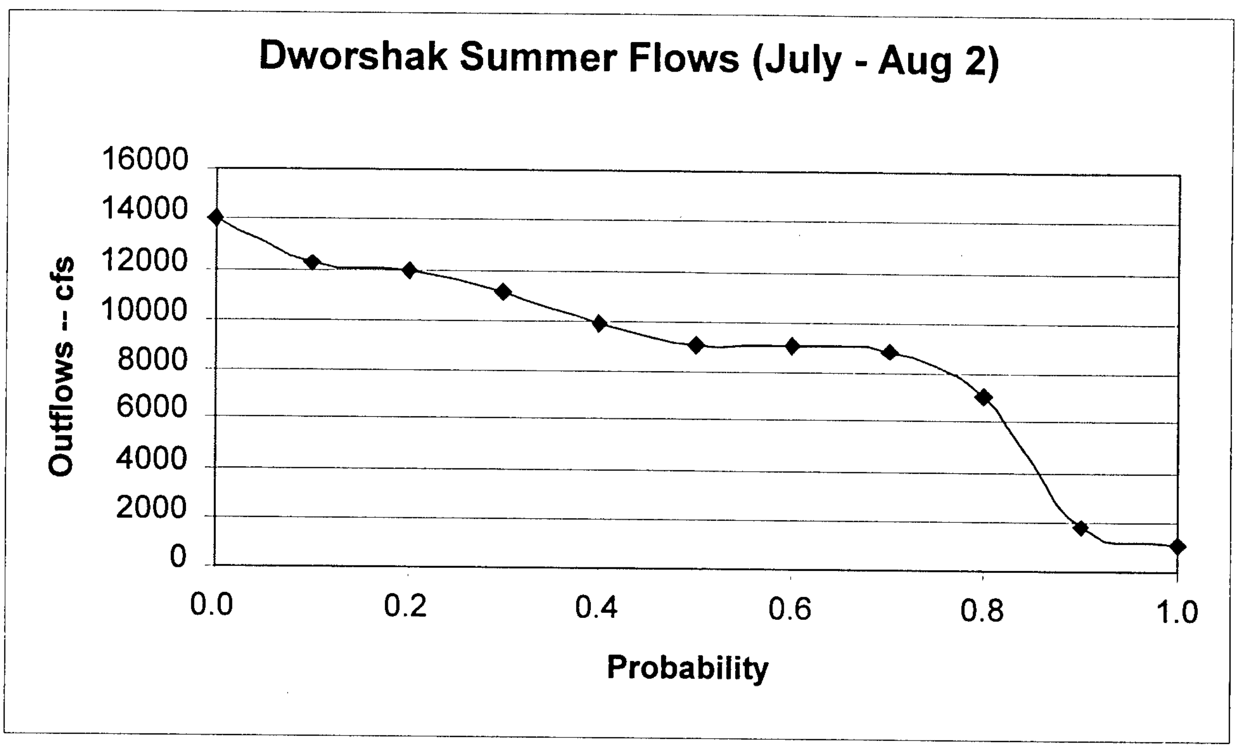



Figure B-4. Alternative A3 Graphs (continued)

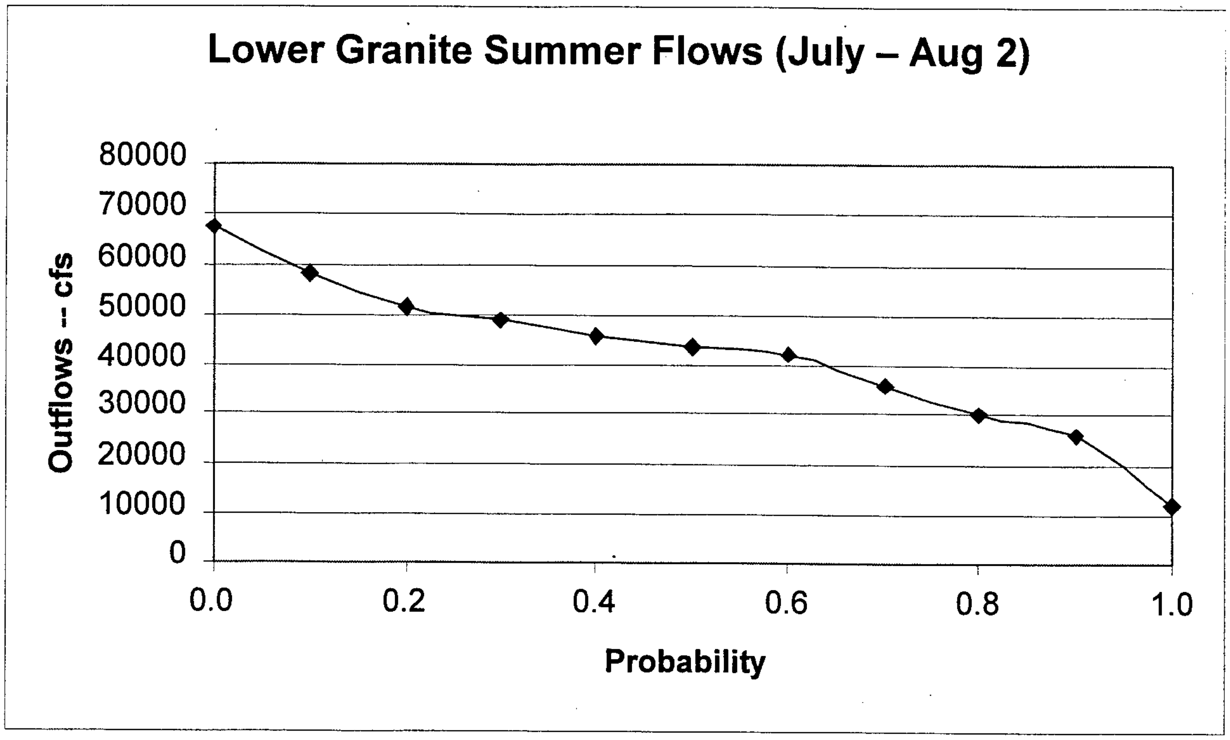
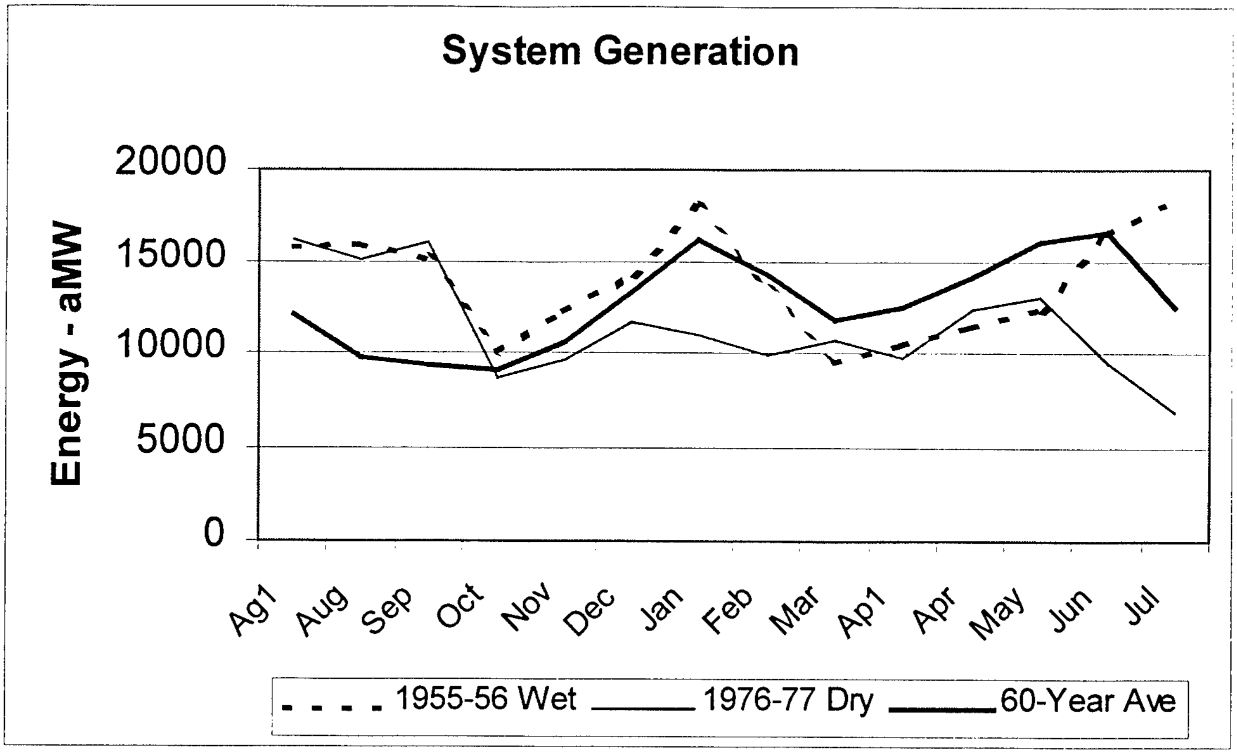


**Figure B-4 Alternative A5 Graphs**



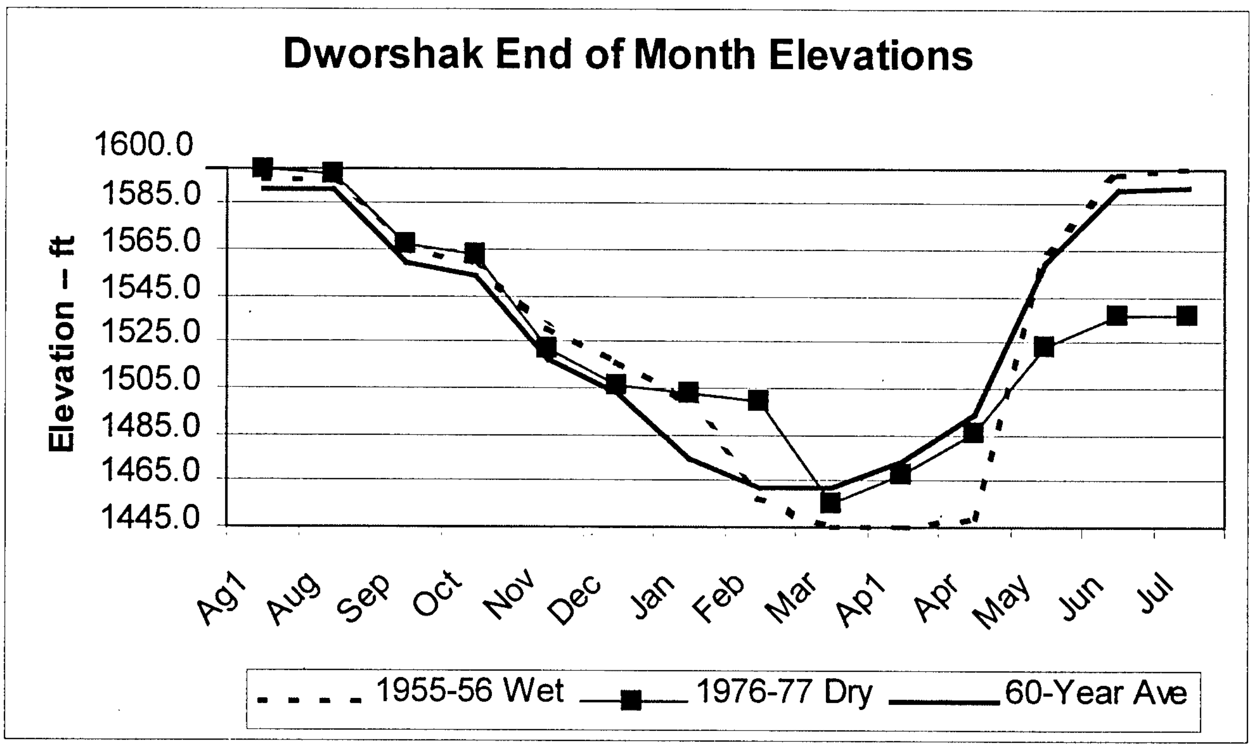
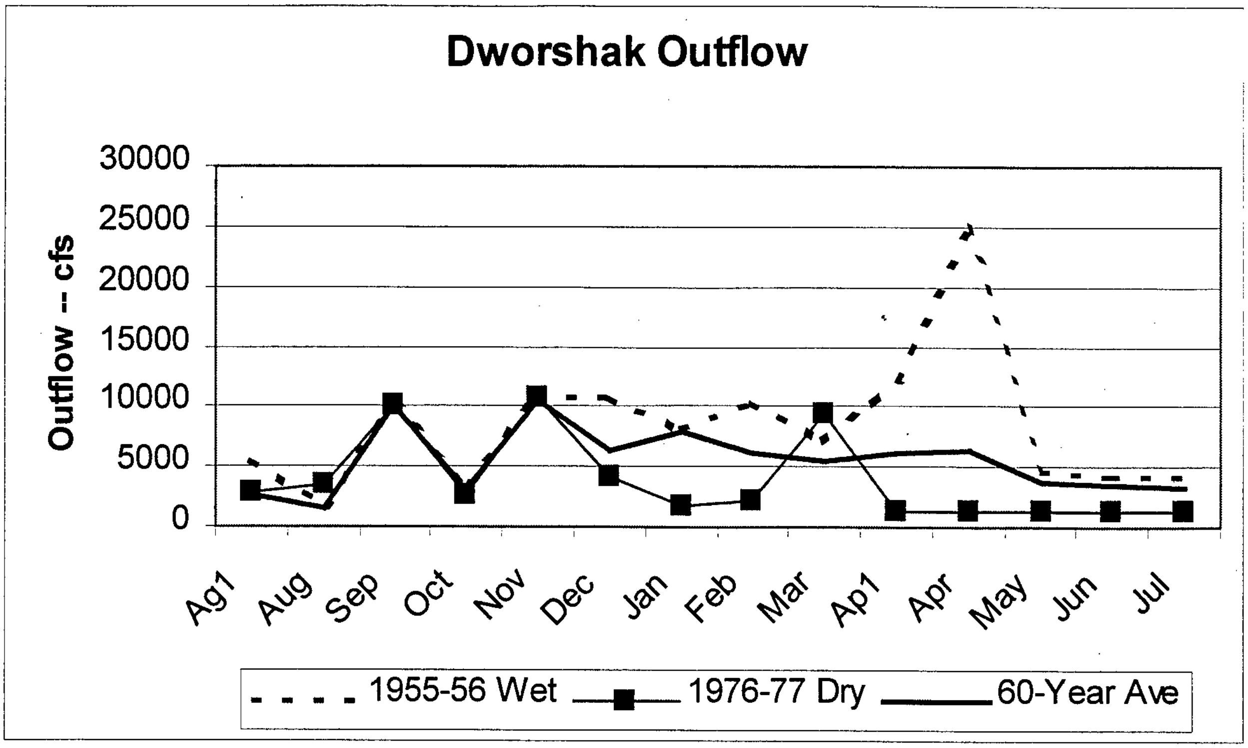



Figure B-4 Alternative A5 Graphs (continued)



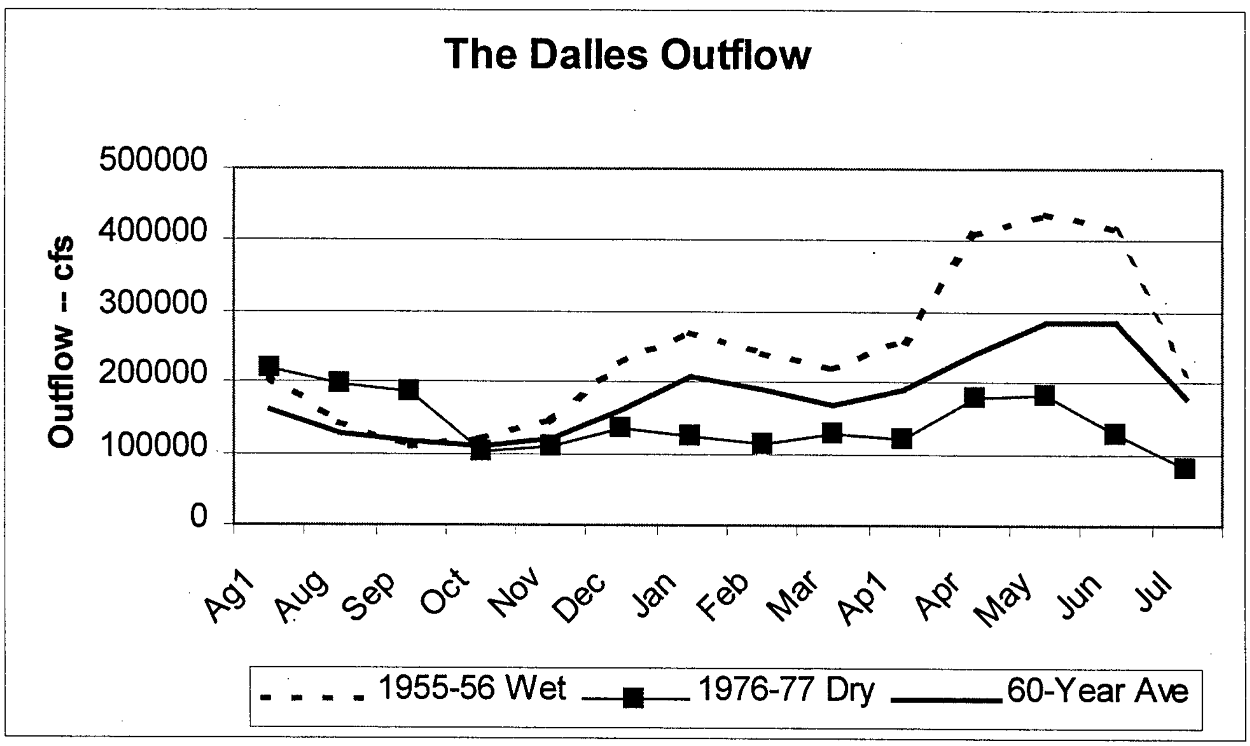
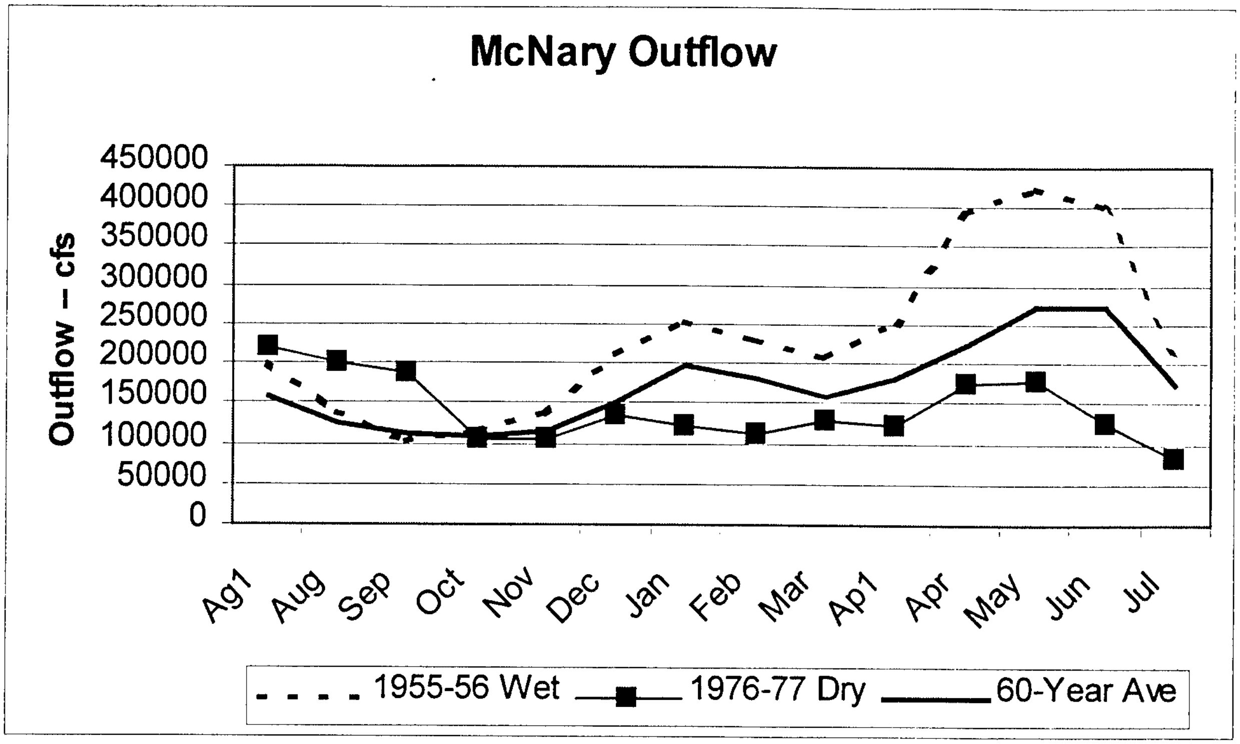



Figure B-4 Alternative A5 Graphs (continued)



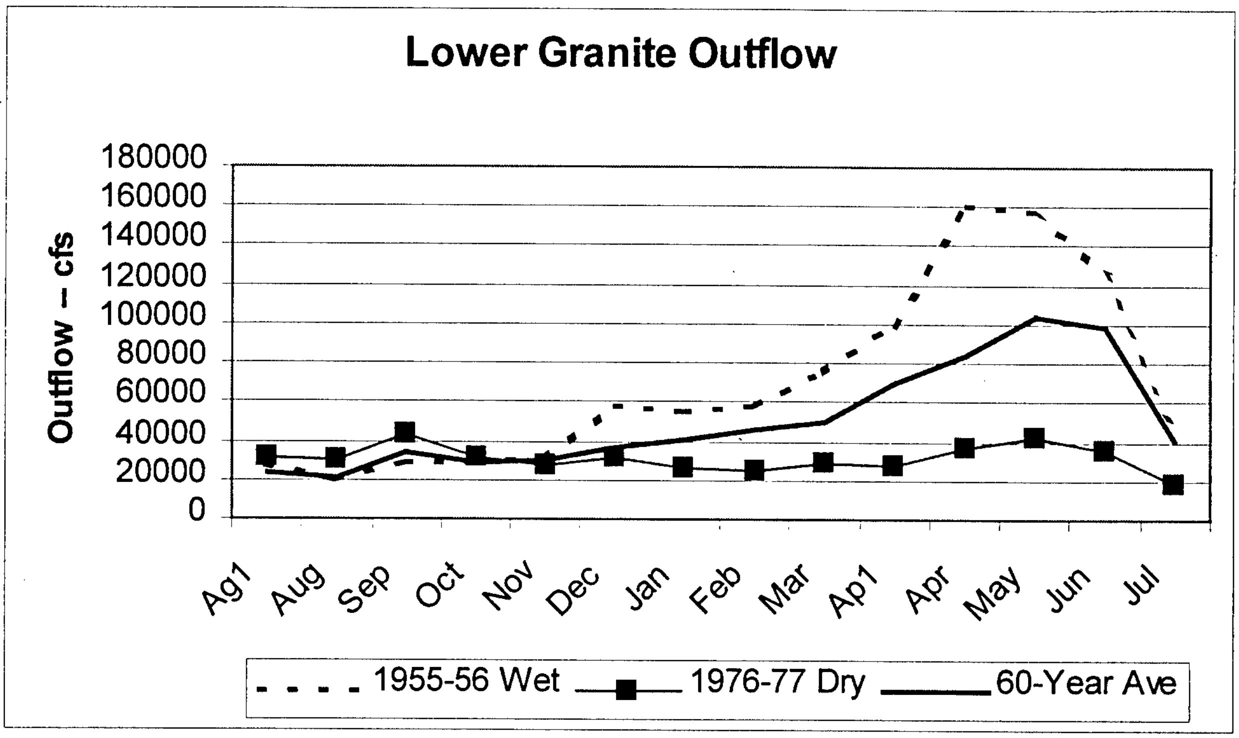
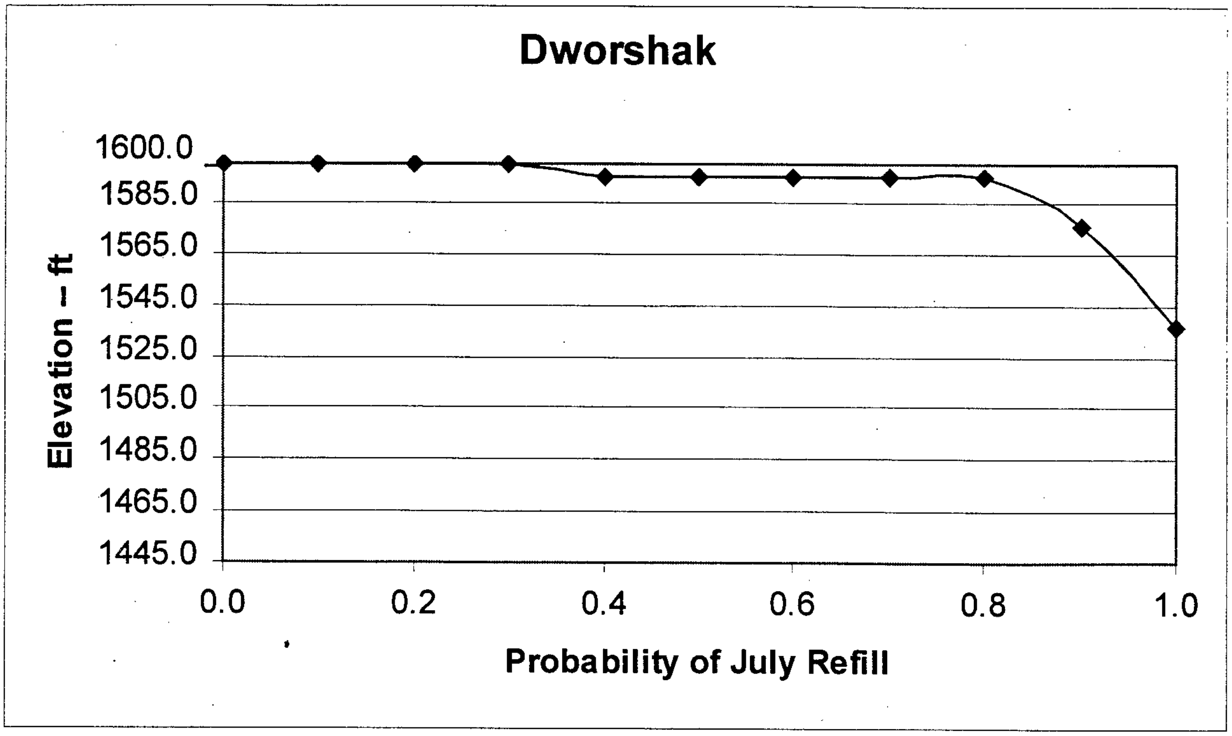



Figure B-4 Alternative A5 Graphs (continued)



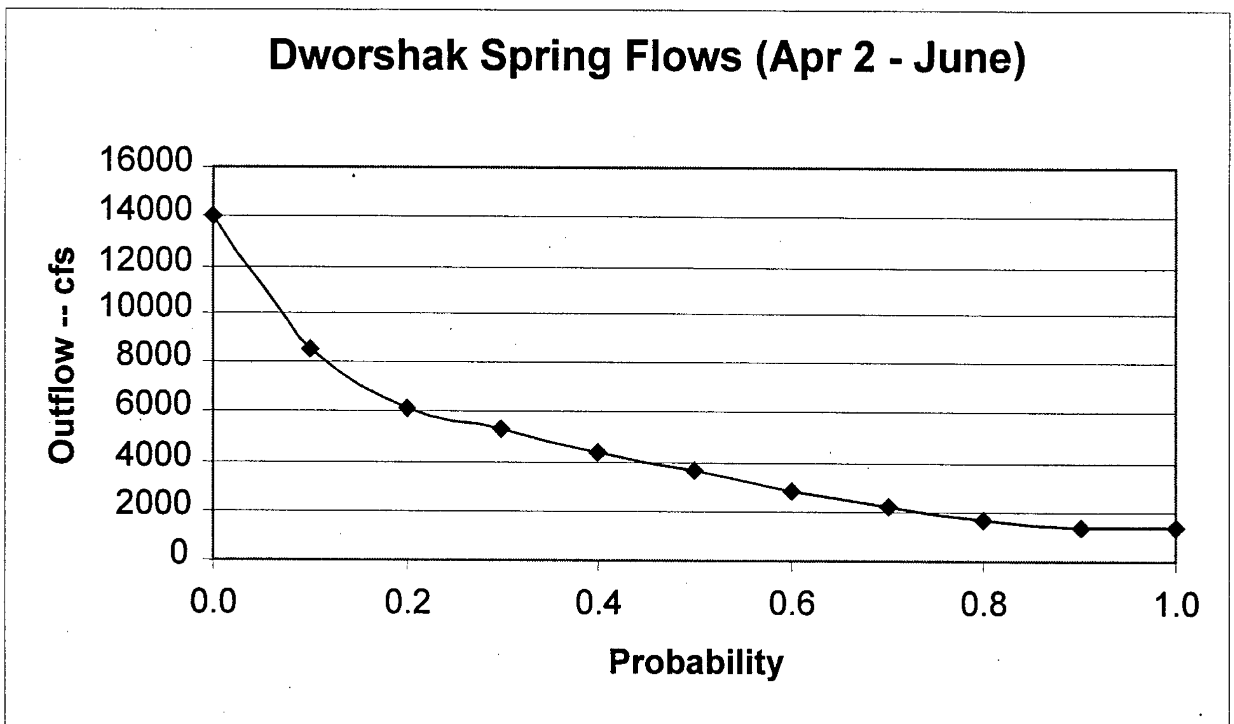
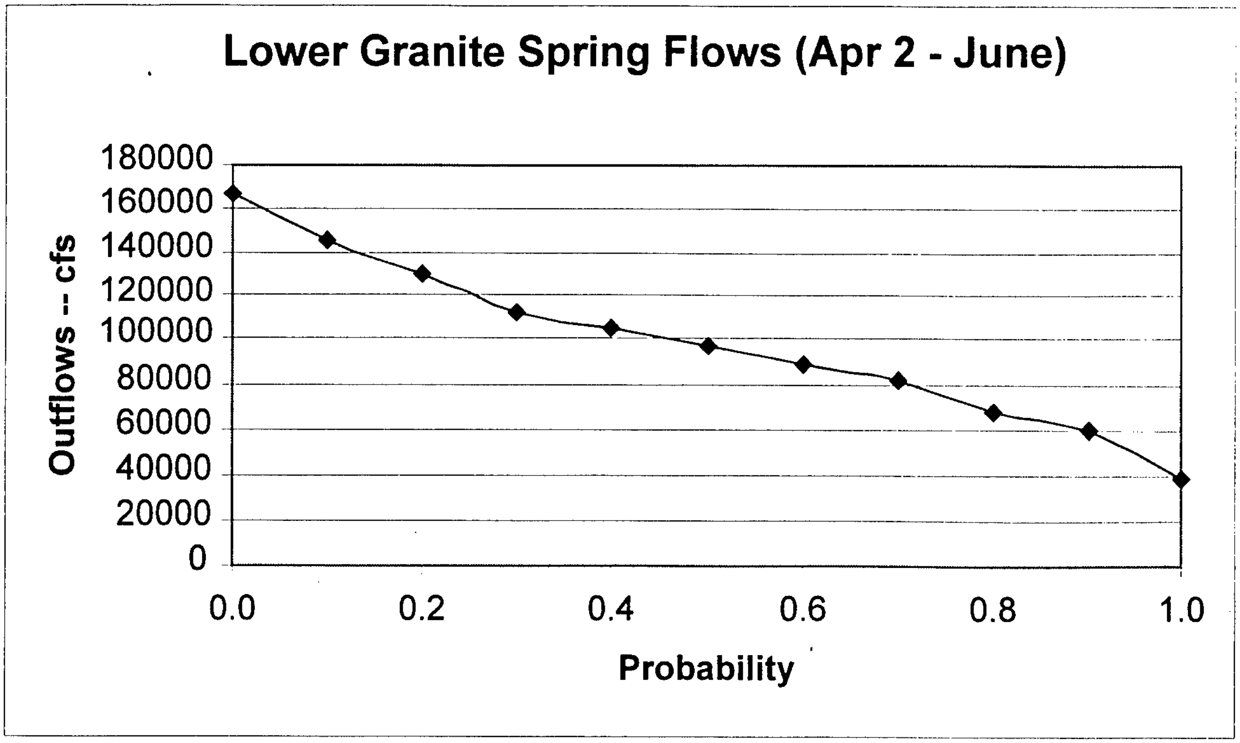



Figure B-4 Alternative A5 Graphs (continued)



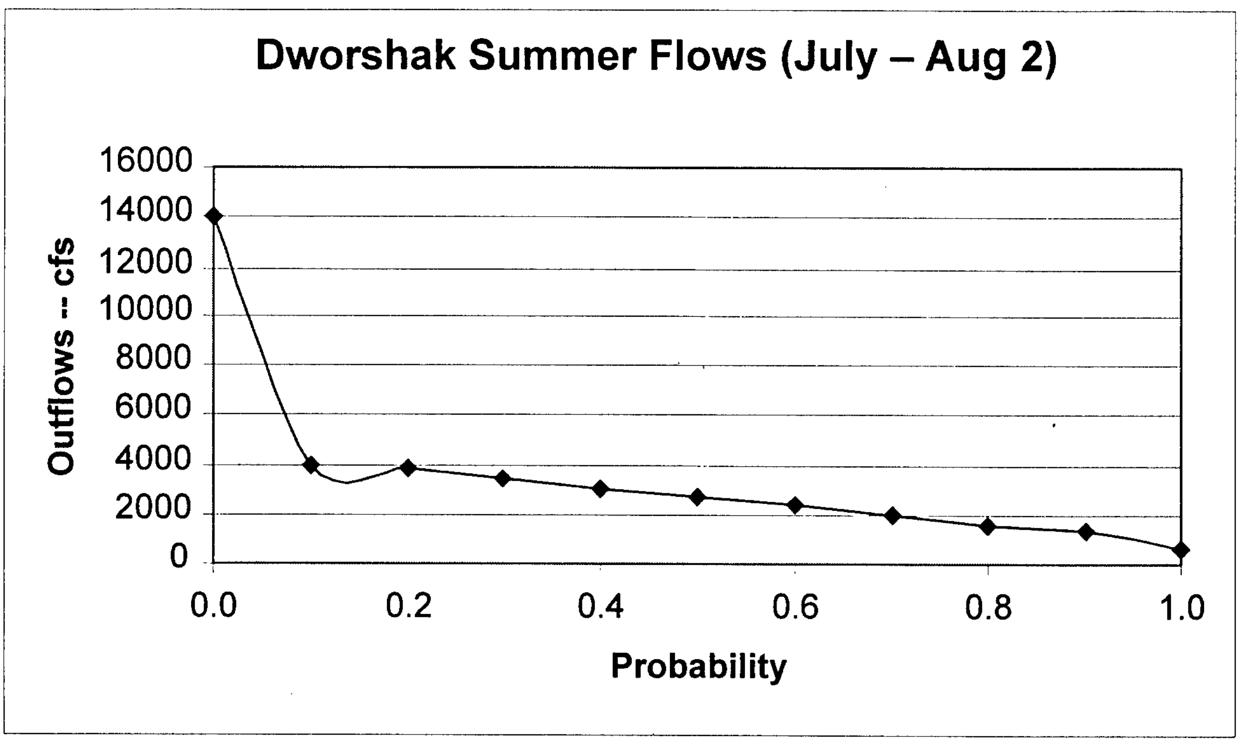



Figure B-4 Alternative A5 Graphs (continued)

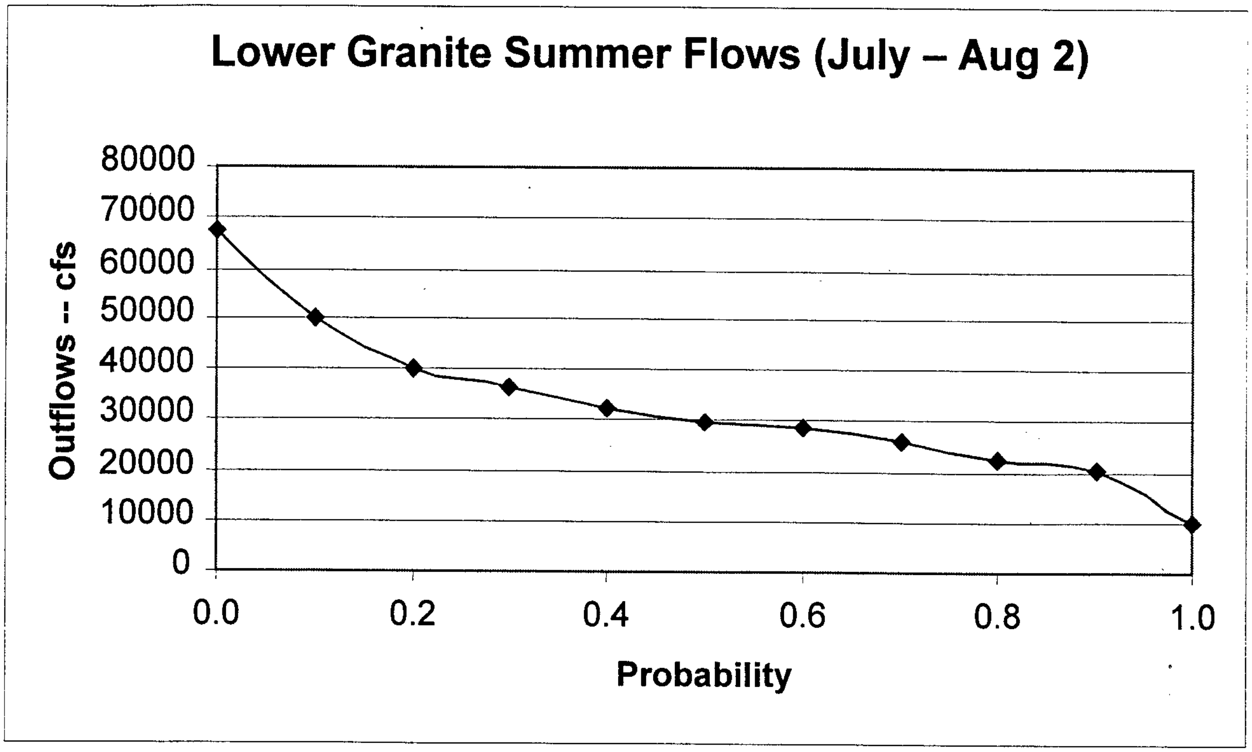
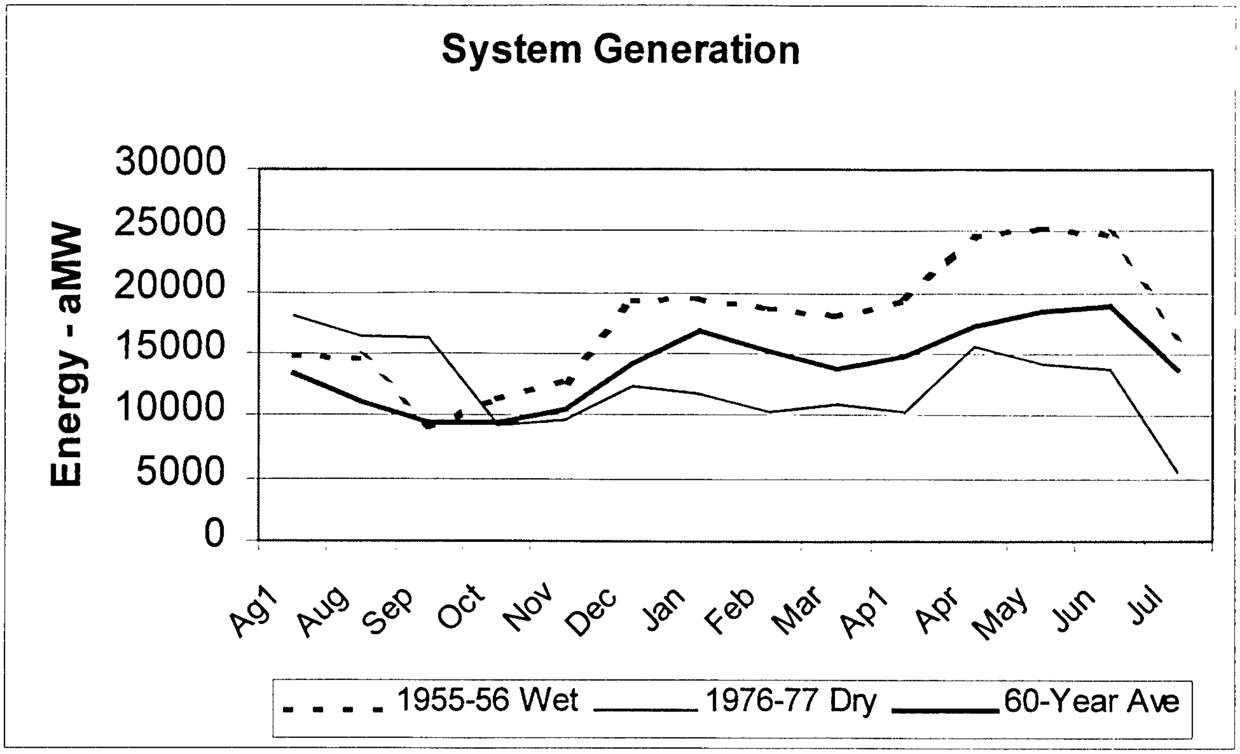


**Figure B-1 Alternative A6a Graphs**



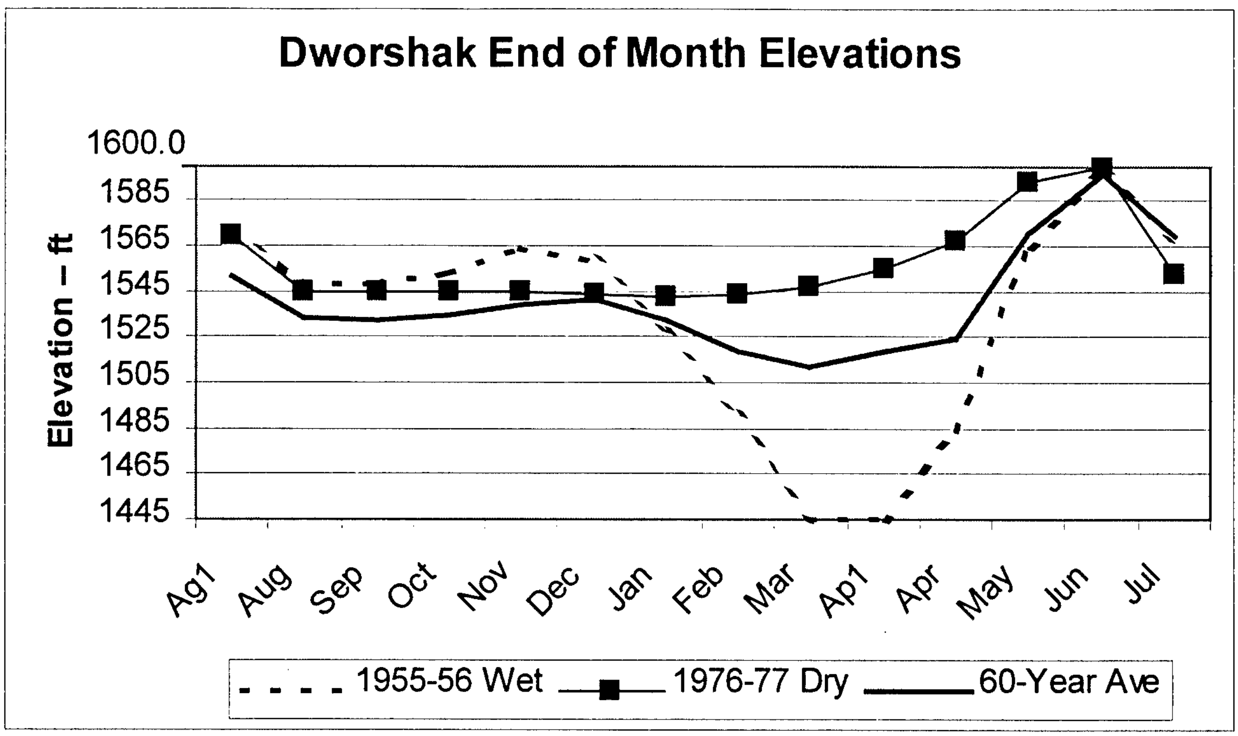
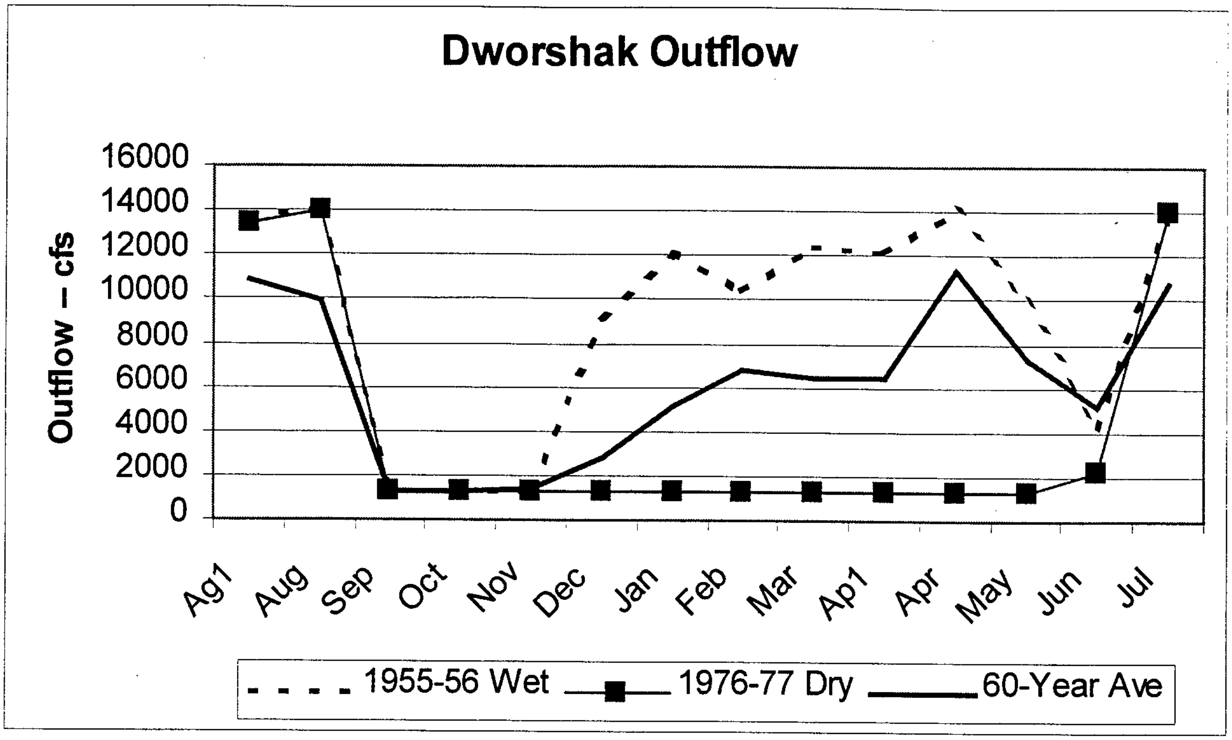



Figure B-5 Alternative A6a Graphs (continued)



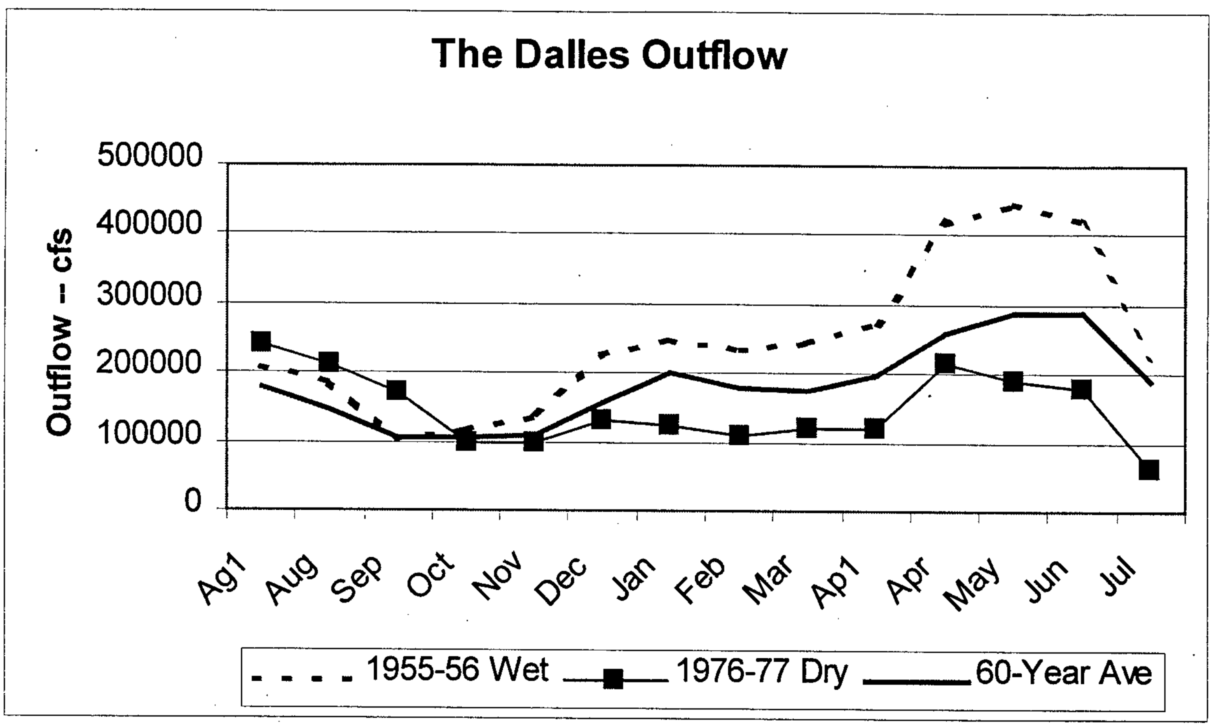
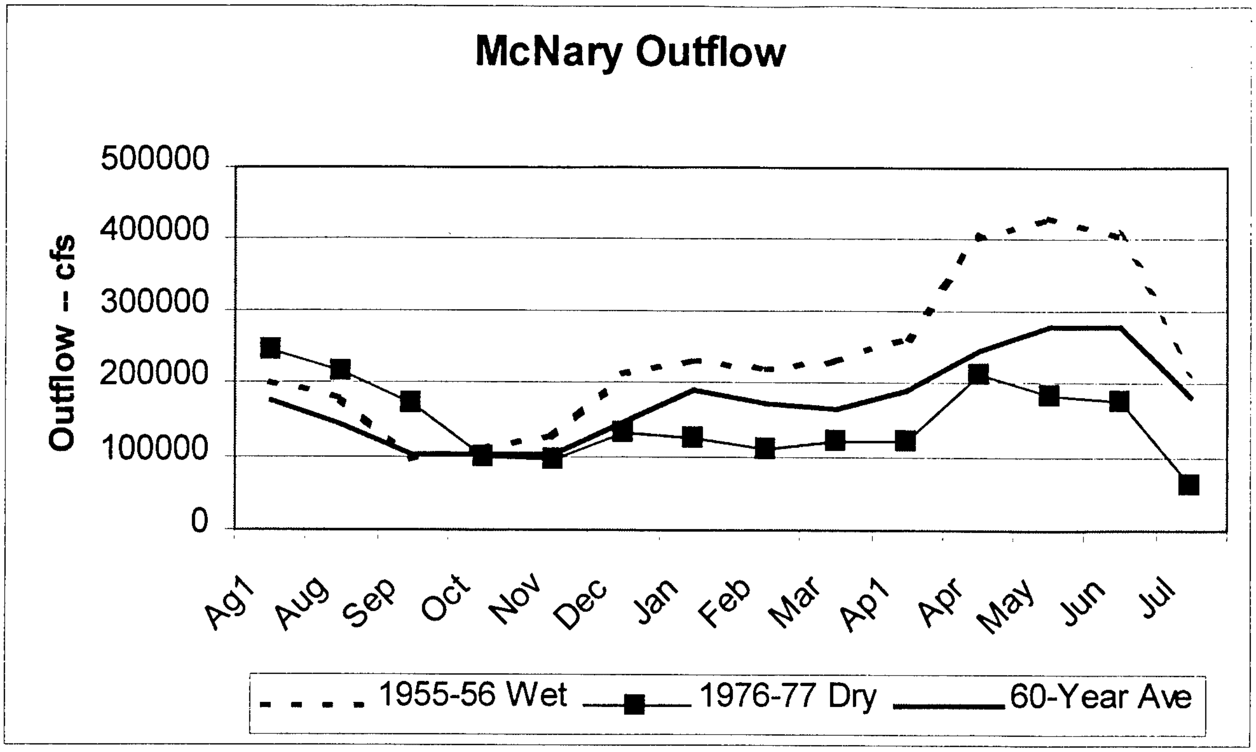



Figure B-5 Alternative A6a Graphs (continued)



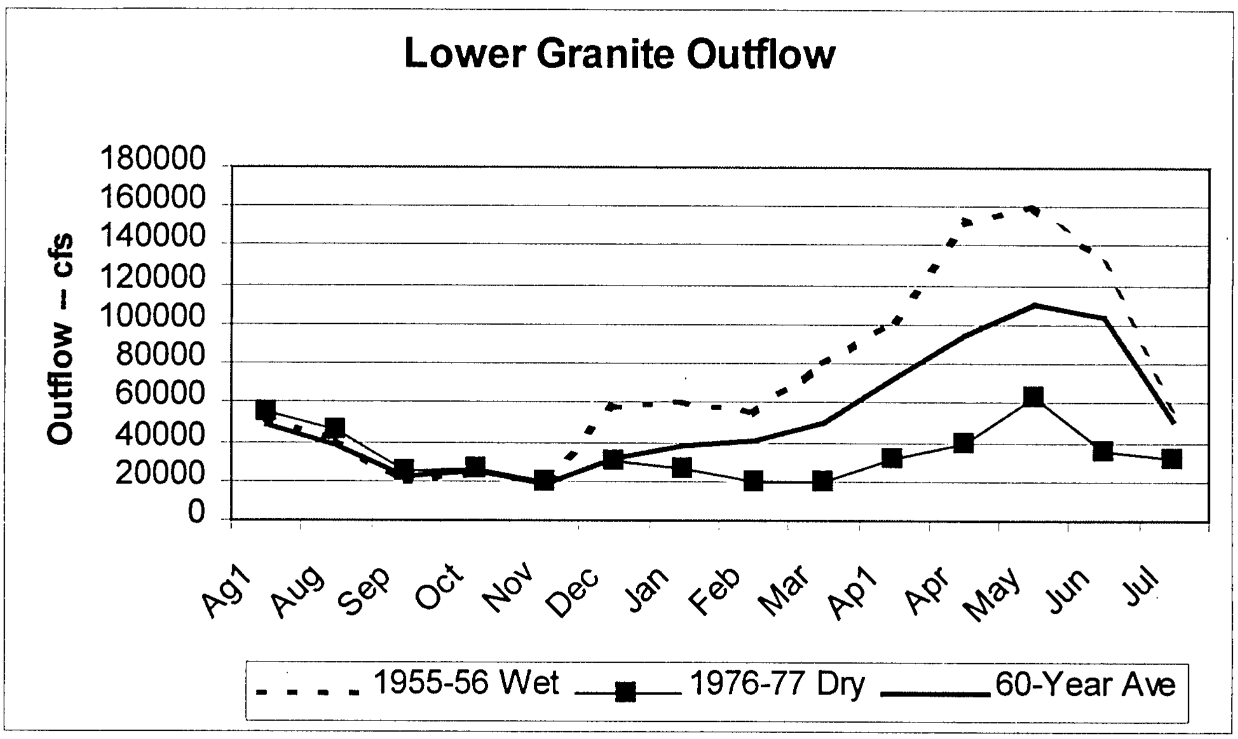
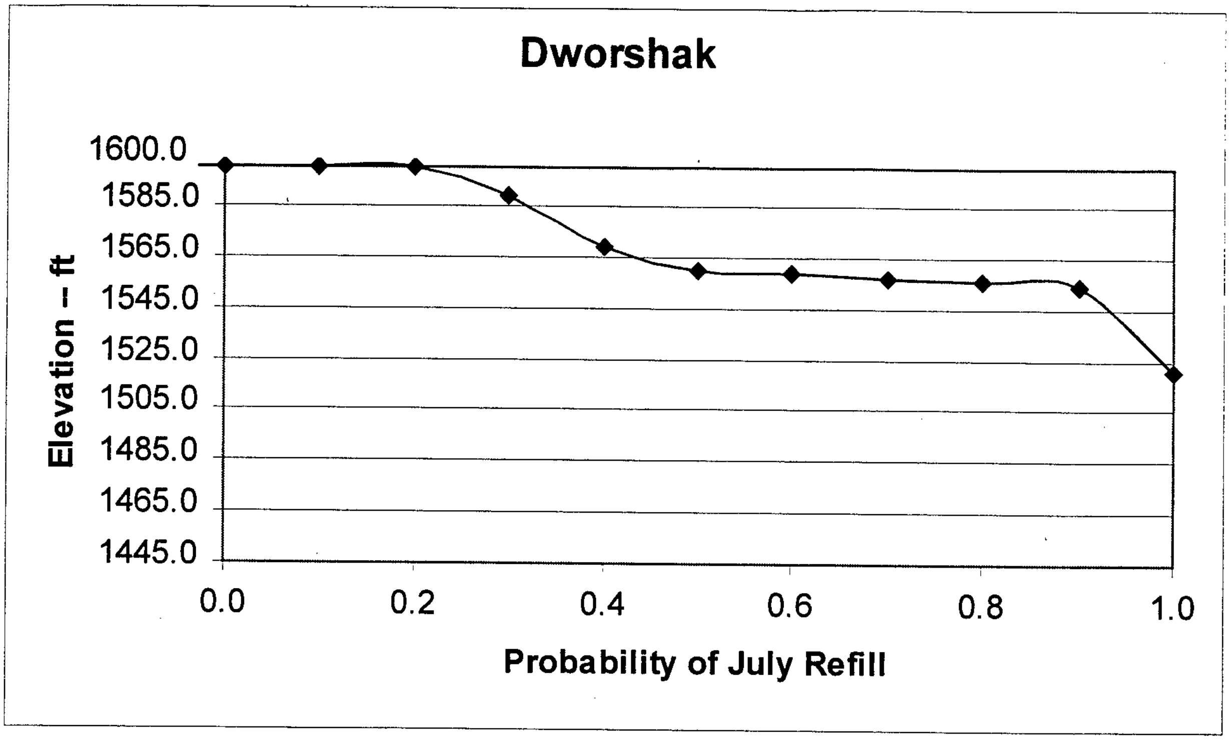



**Figure B-5 Alternative A6a Graphs (continued)**



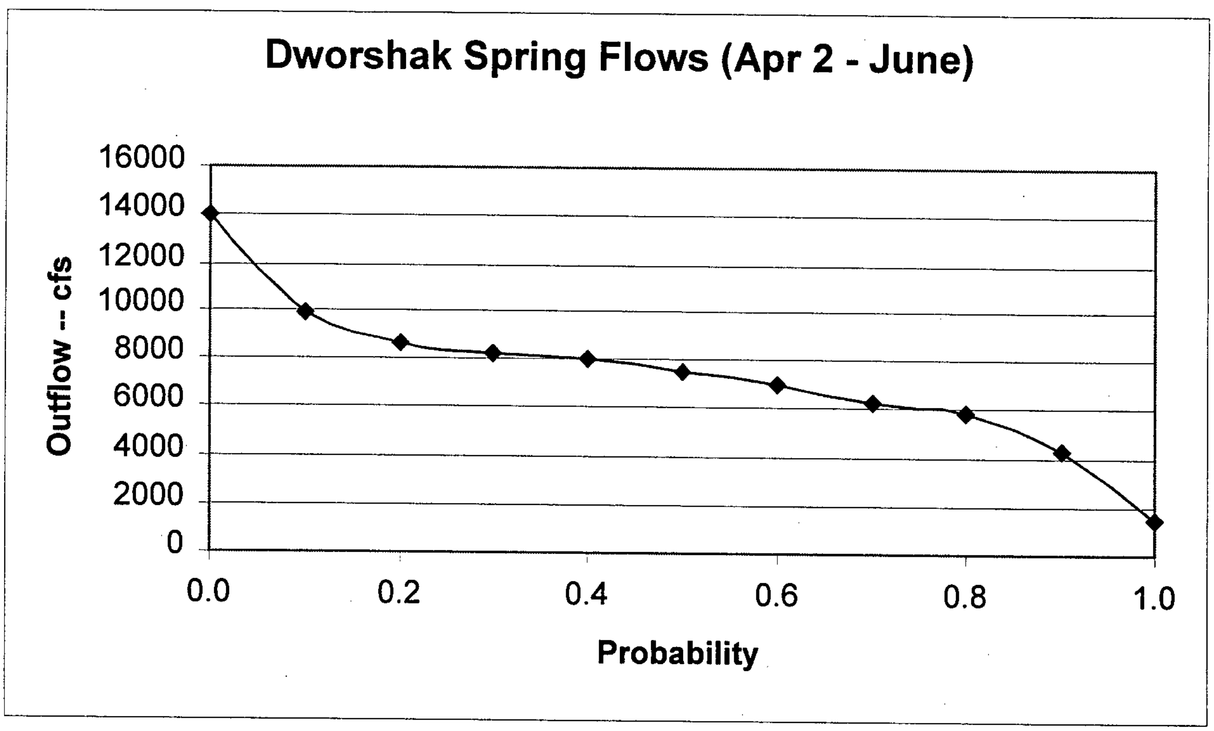
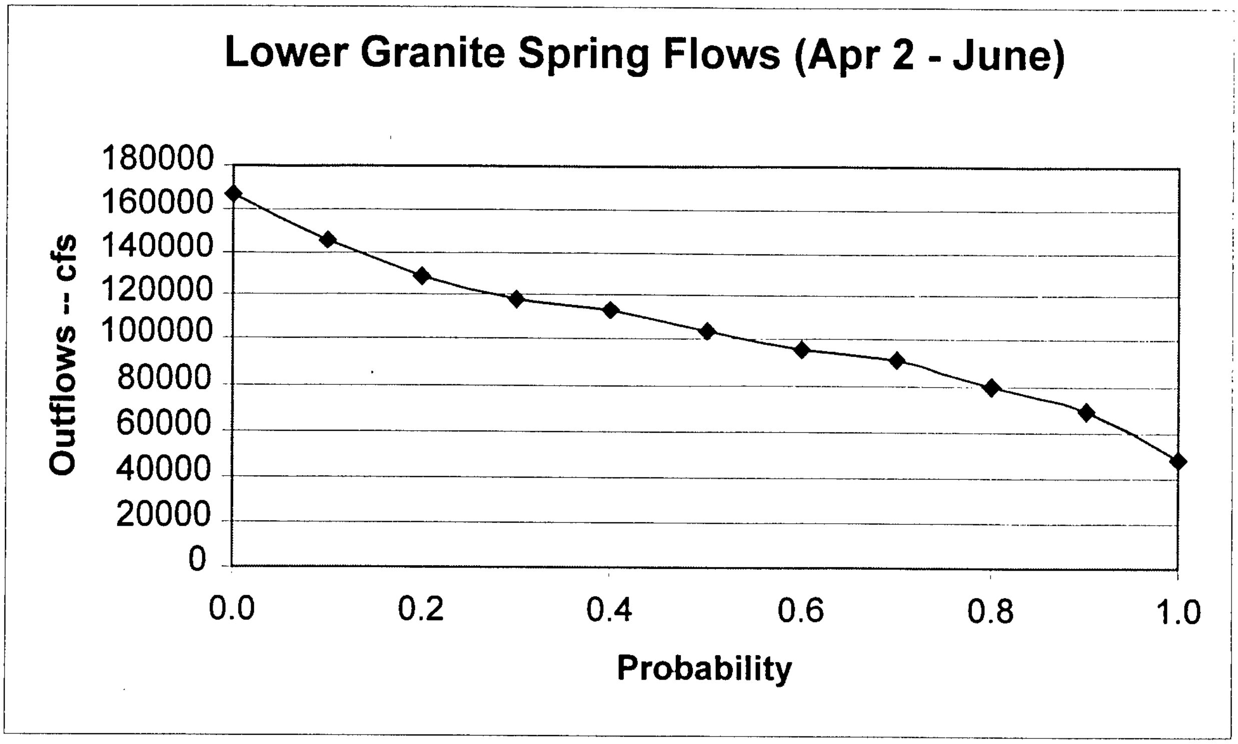



Figure B-5 Alternative A6a Graphs (continued)



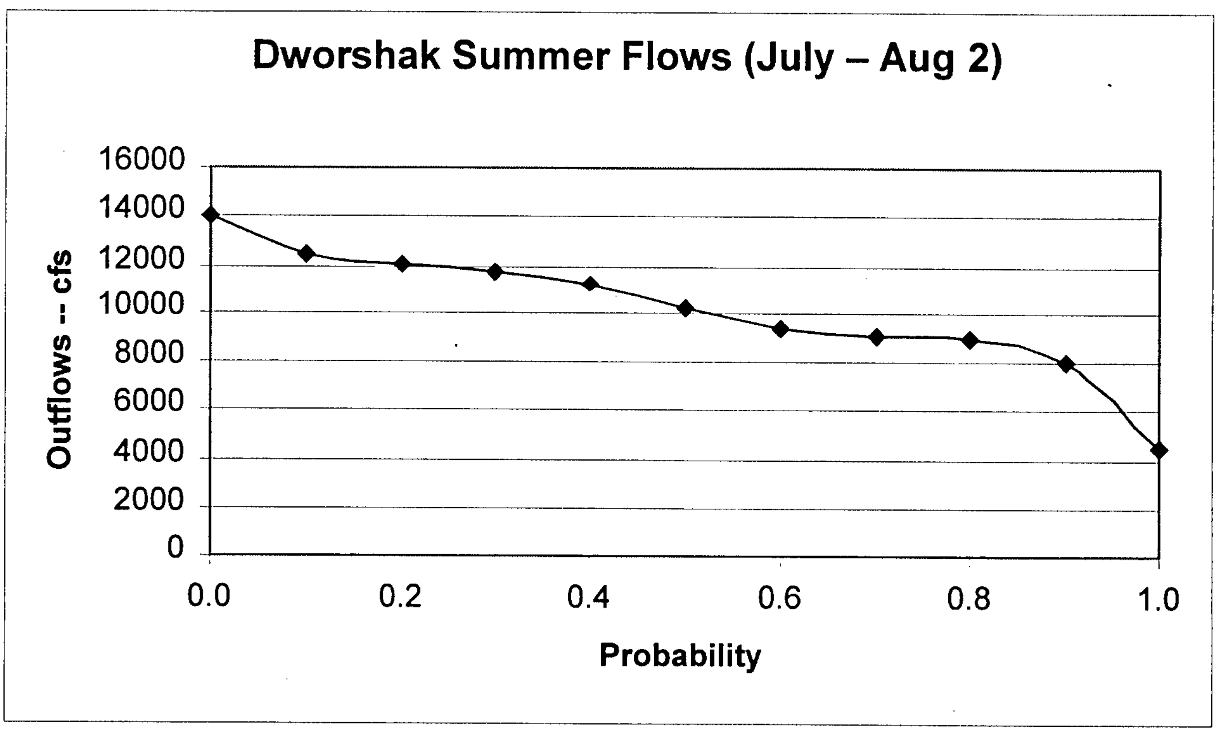



Figure B-5 Alternative A6a Graphs (continued)

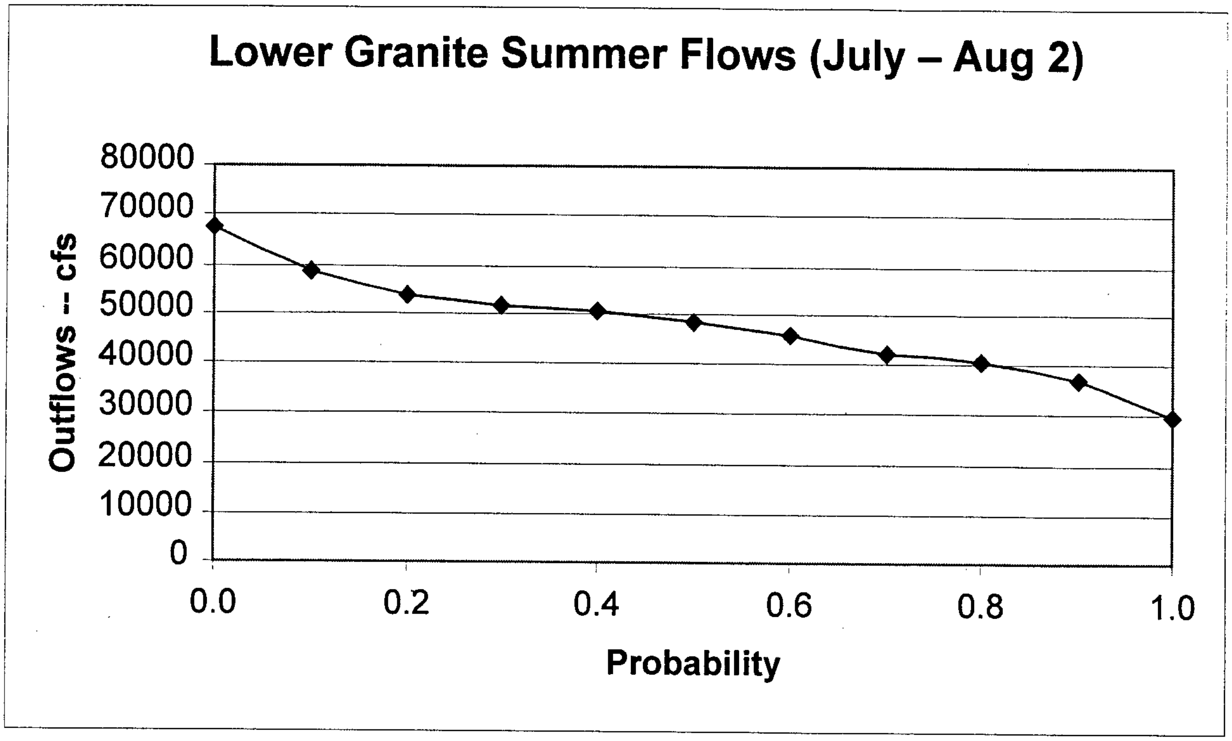
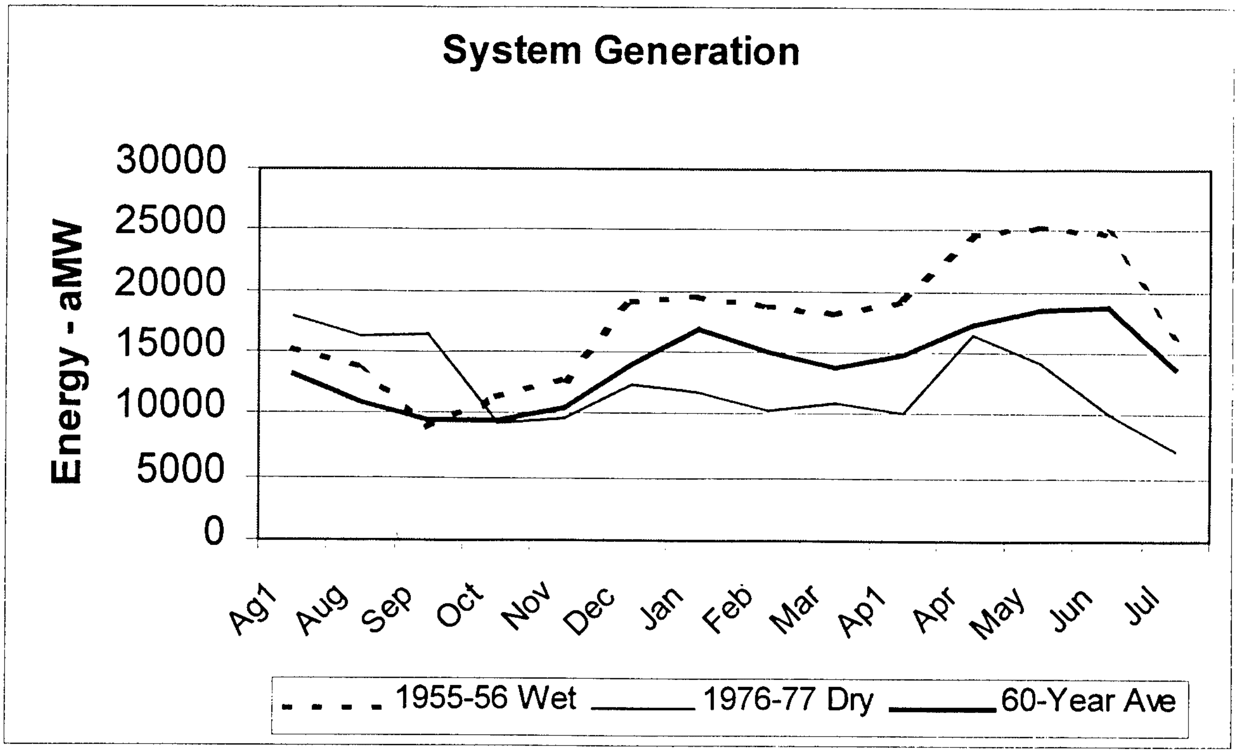


**Figure B-6 Alternative A6b Graphs**



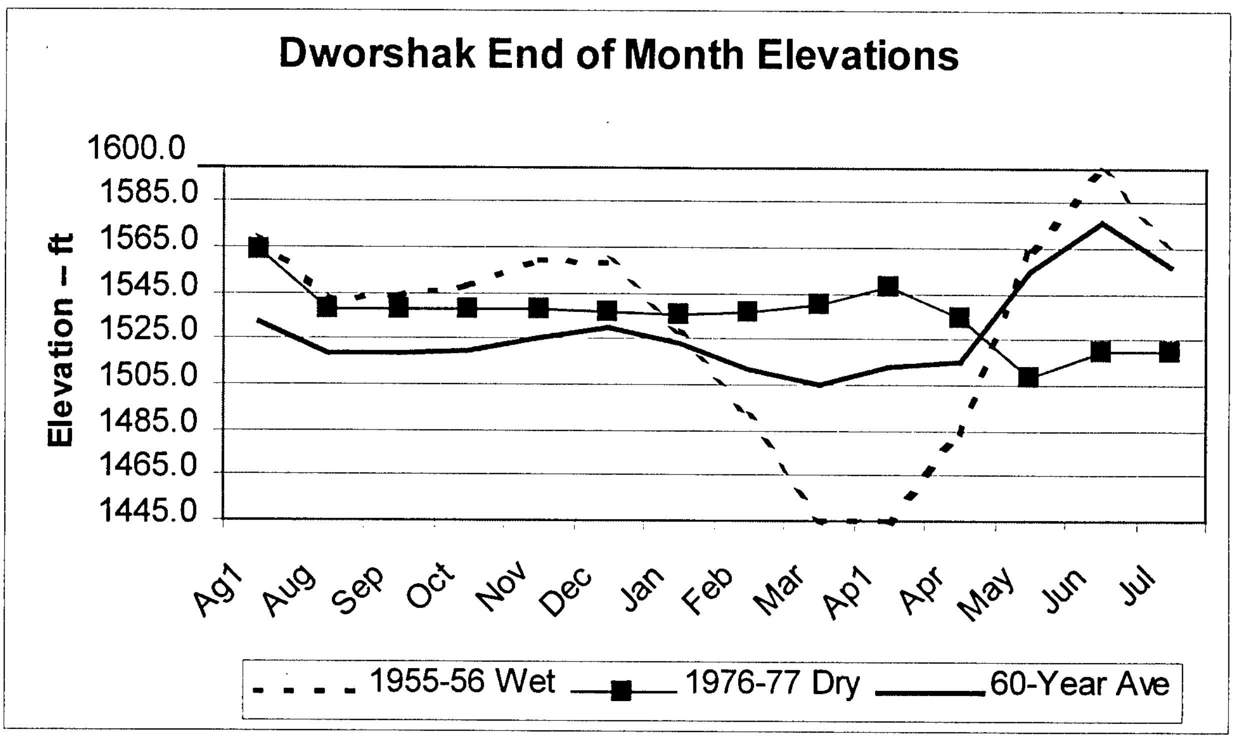
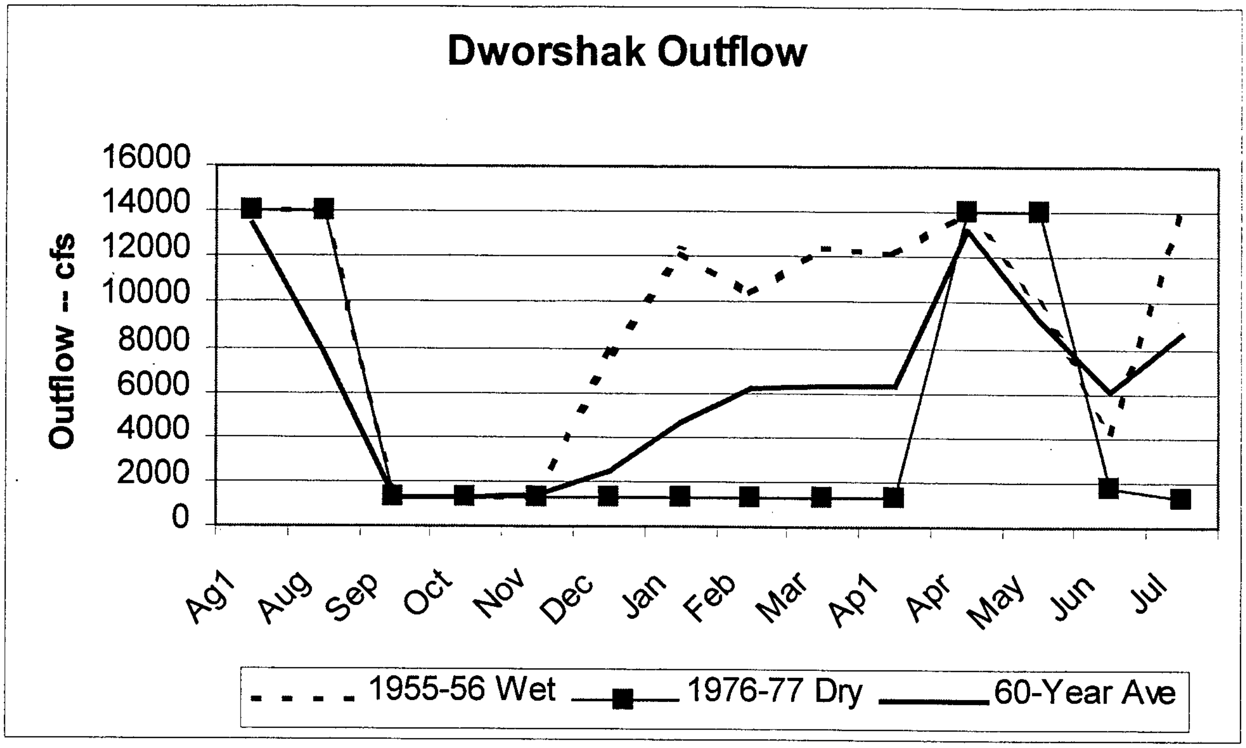



Figure B-6 Alternative A6b Graphs (continued)



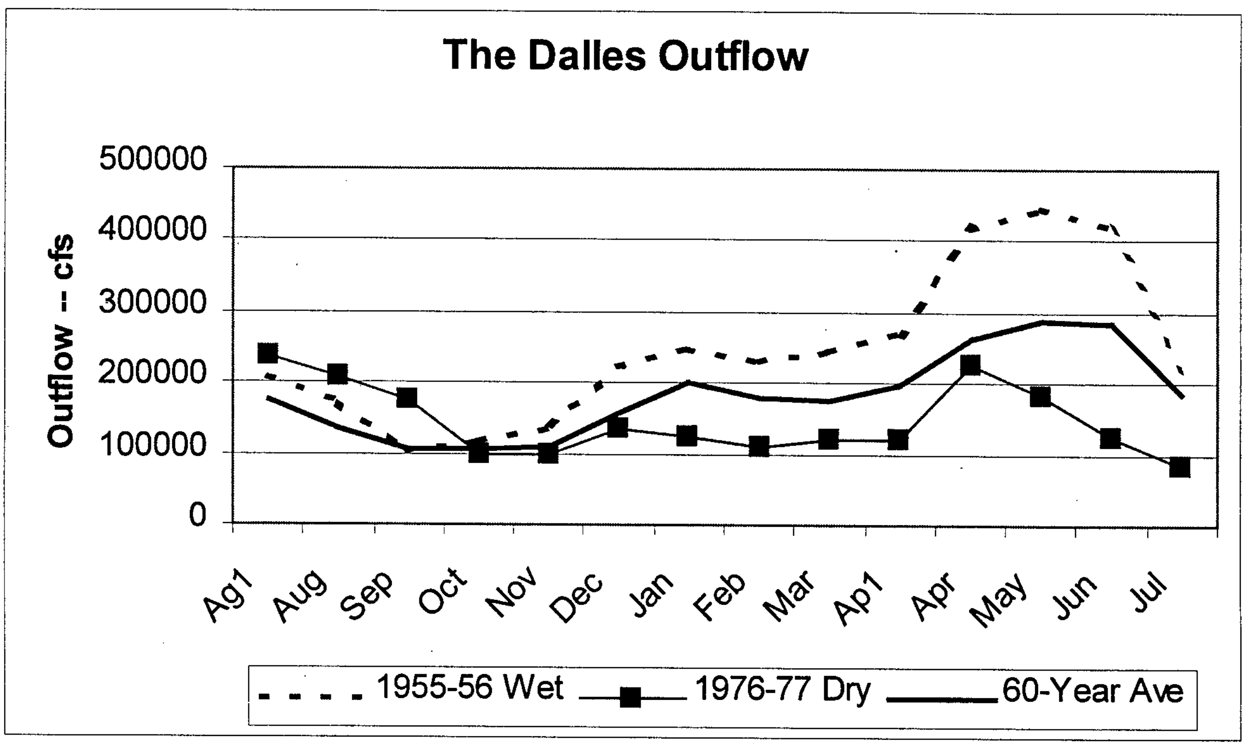
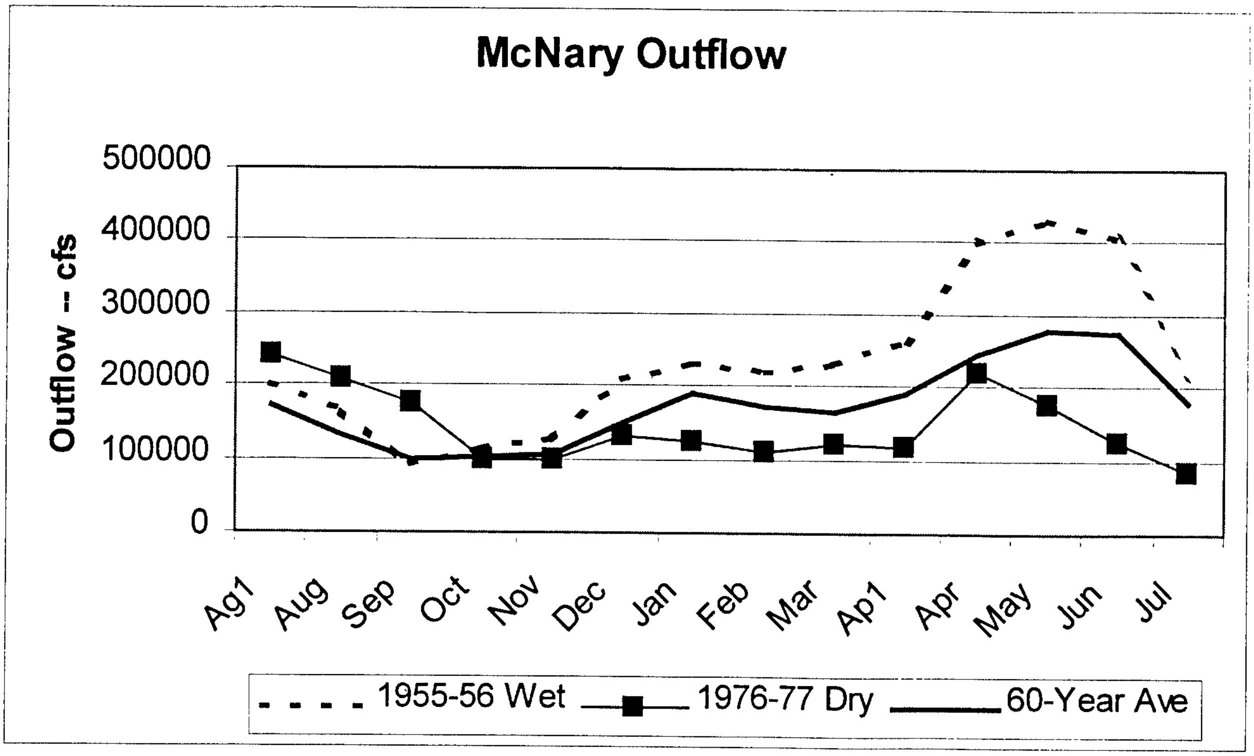



Figure B-6 Alternative A6b Graphs (continued)



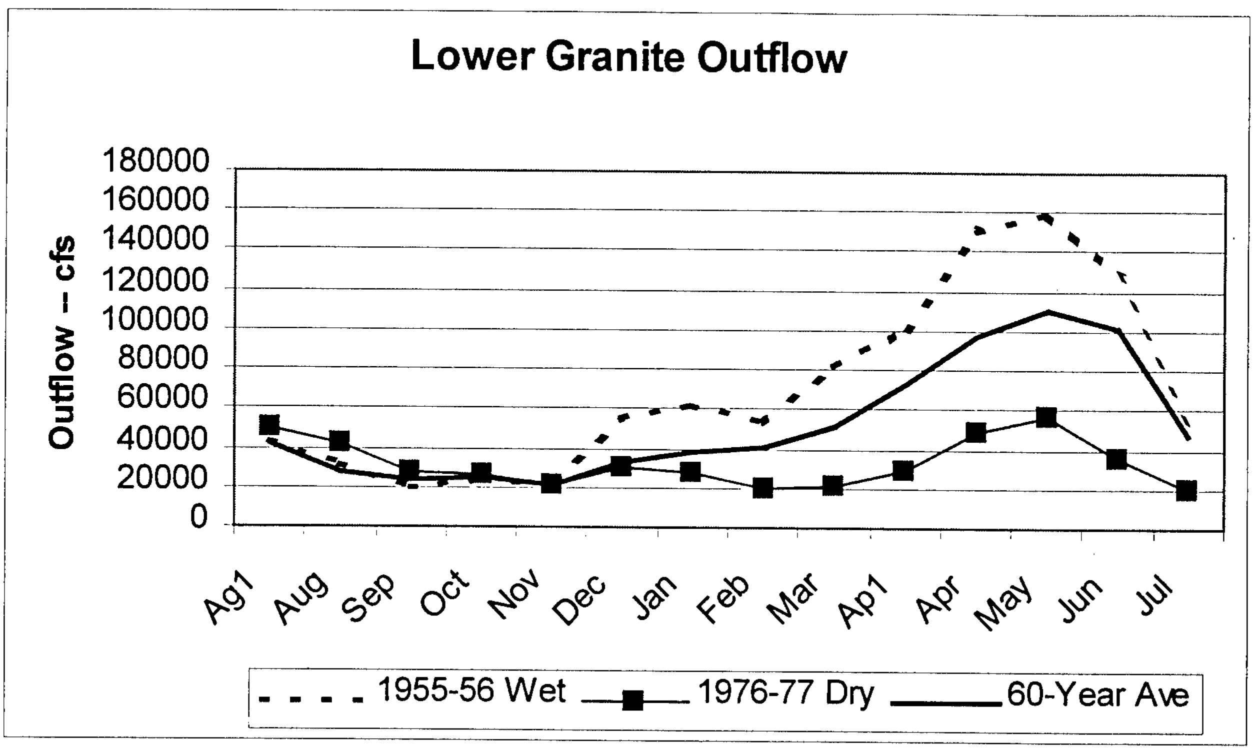
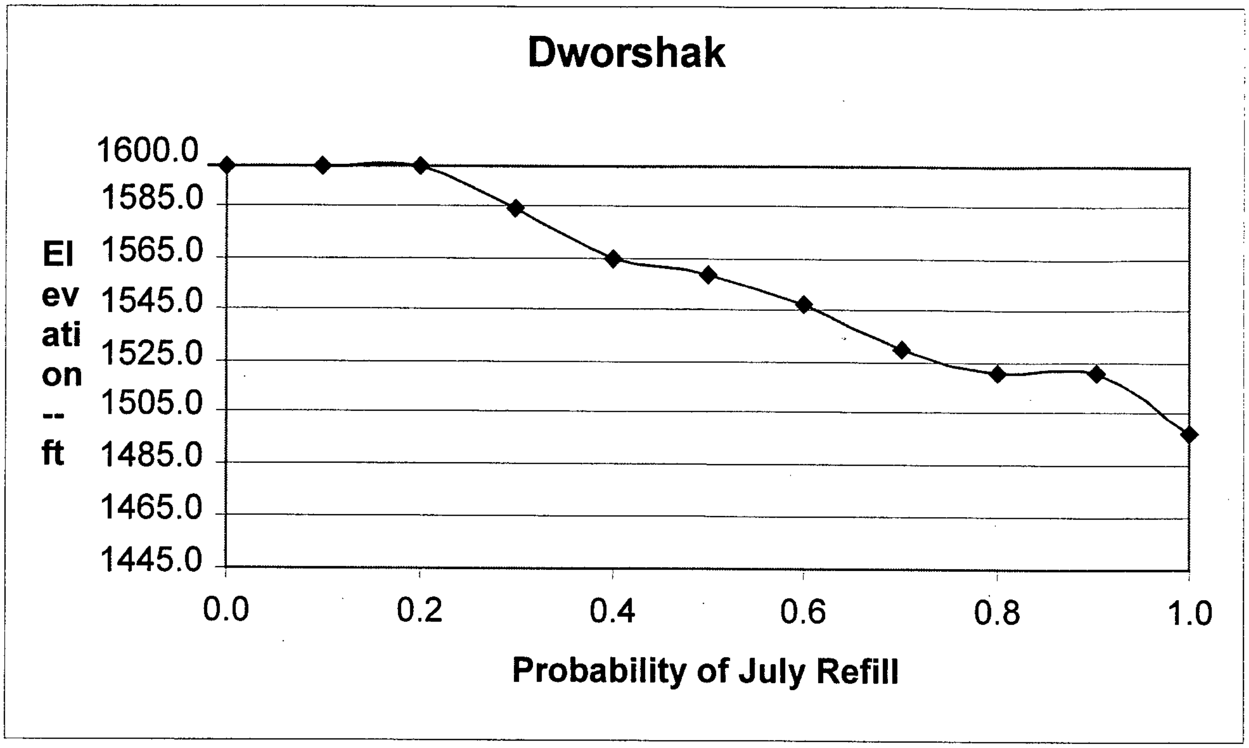
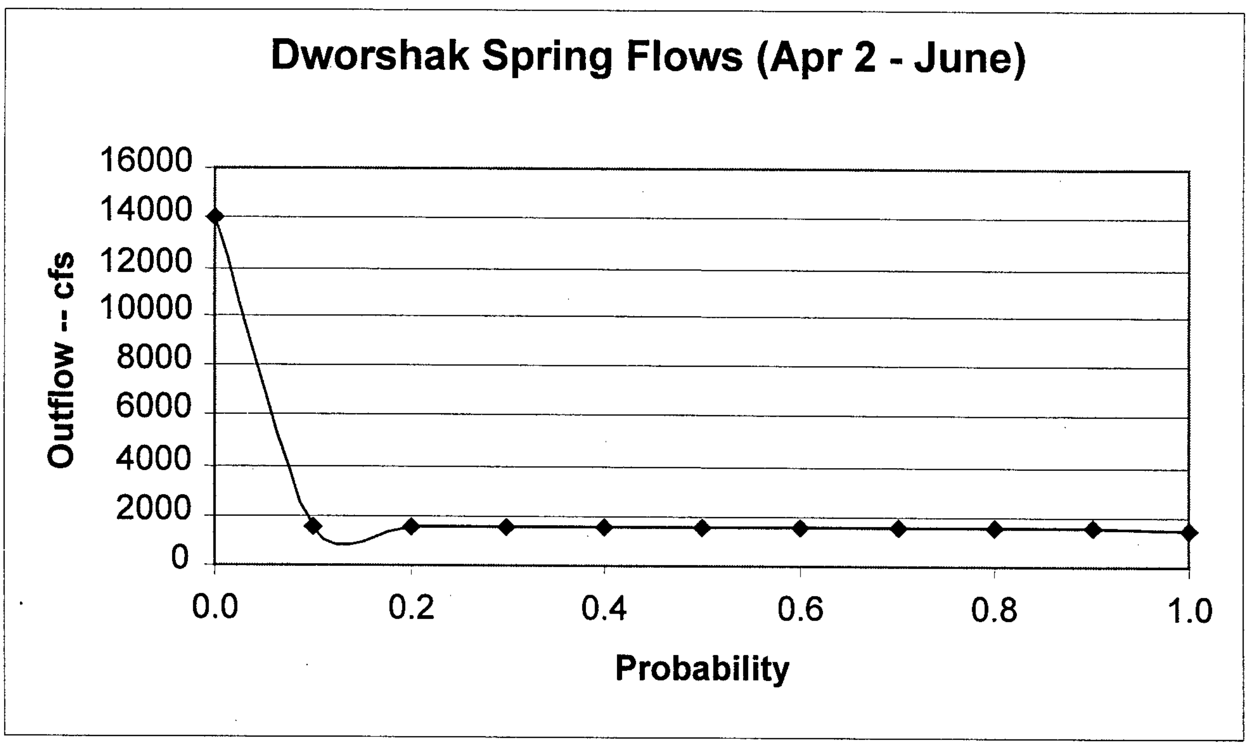



Figure B-6 Alternative A6b Graphs (continued)



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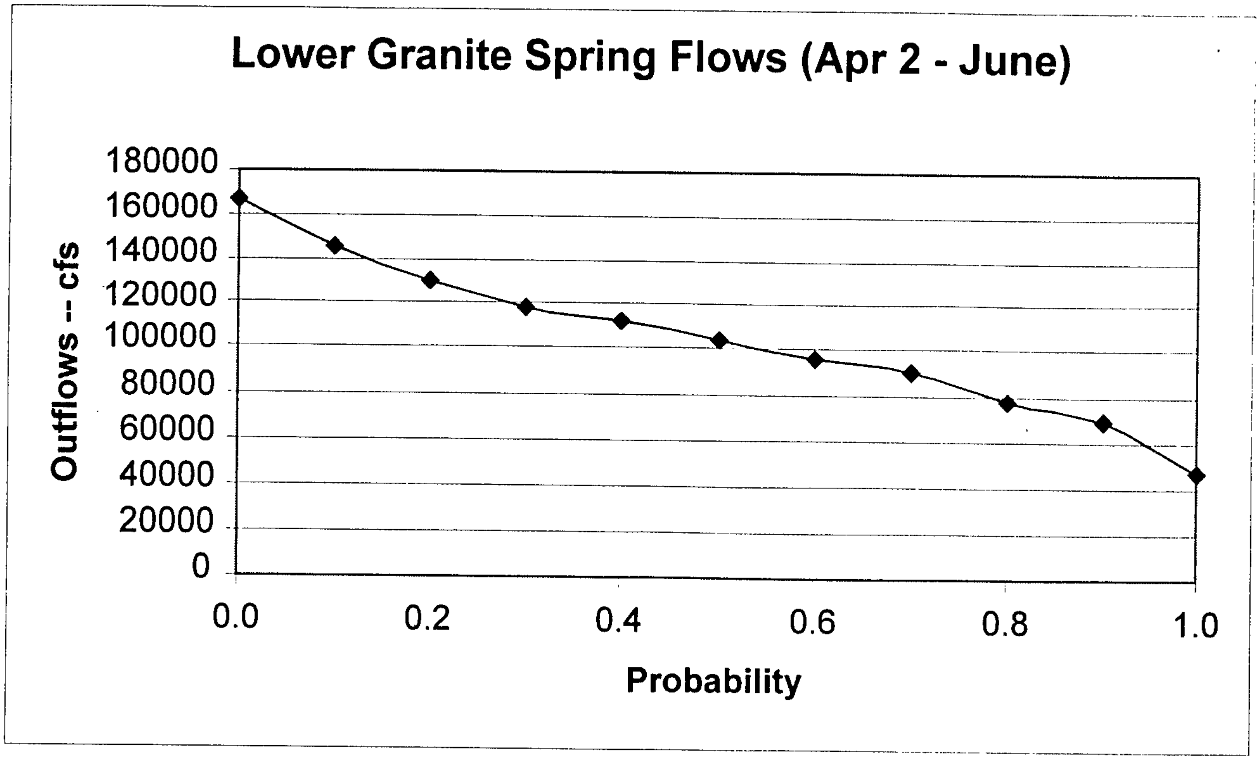


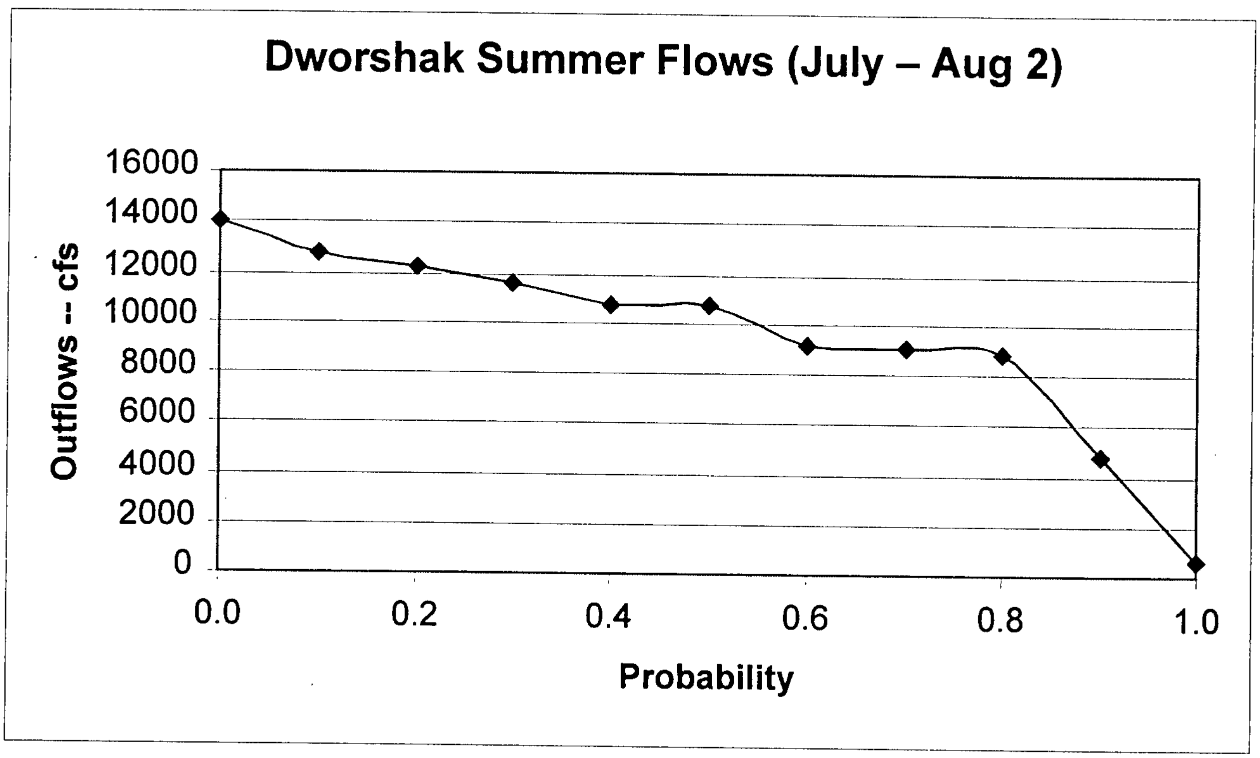



Figure B-6 Alternative A6b Graphs (continued)

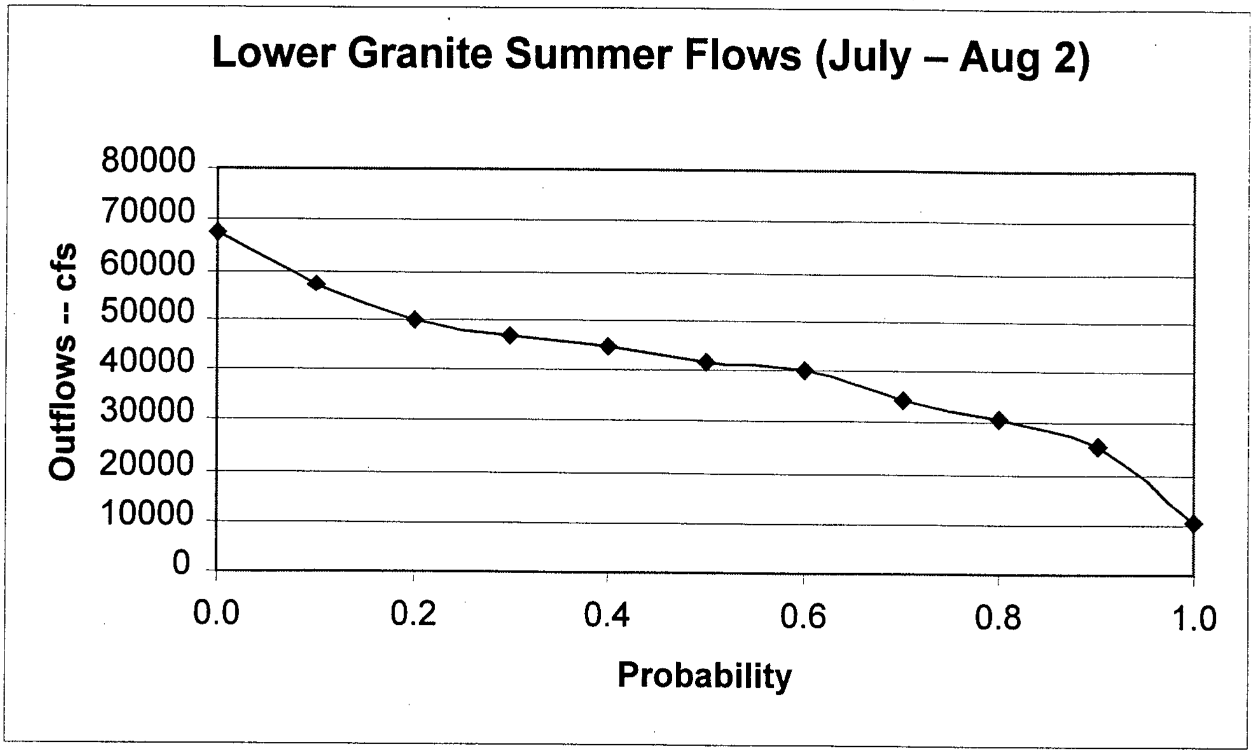
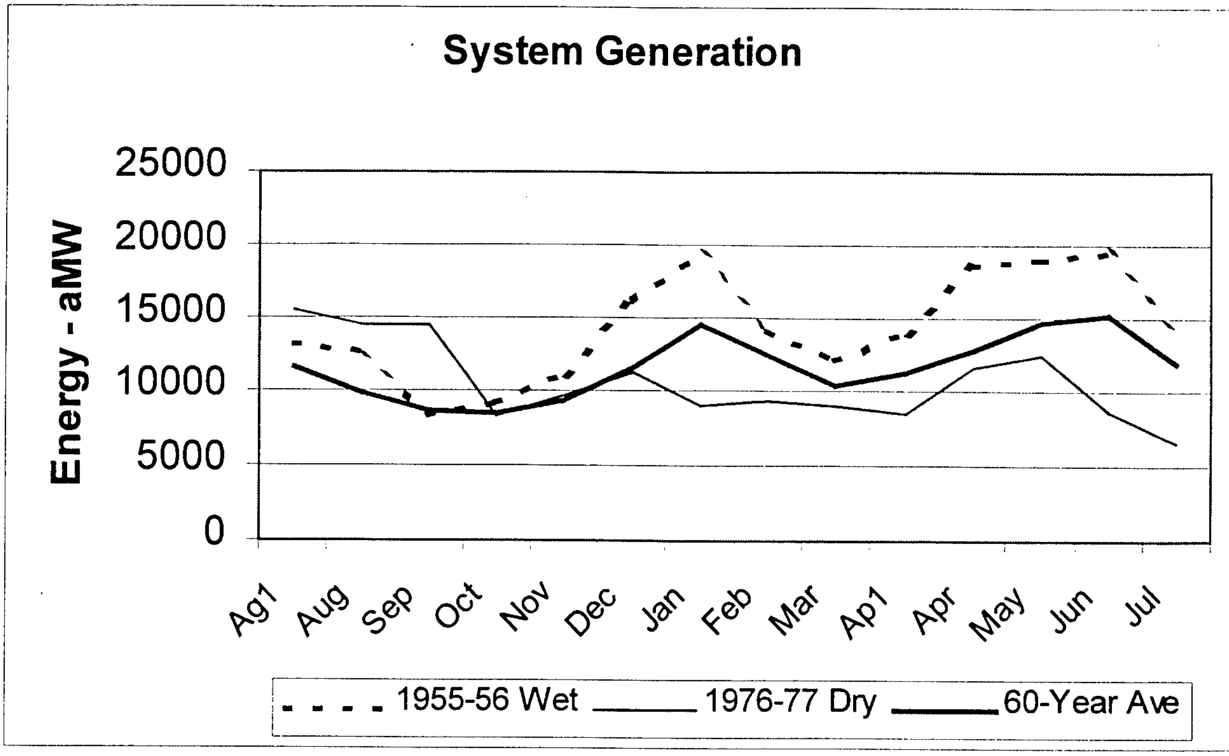


**Figure B-2 Alternative B1 Graphs**



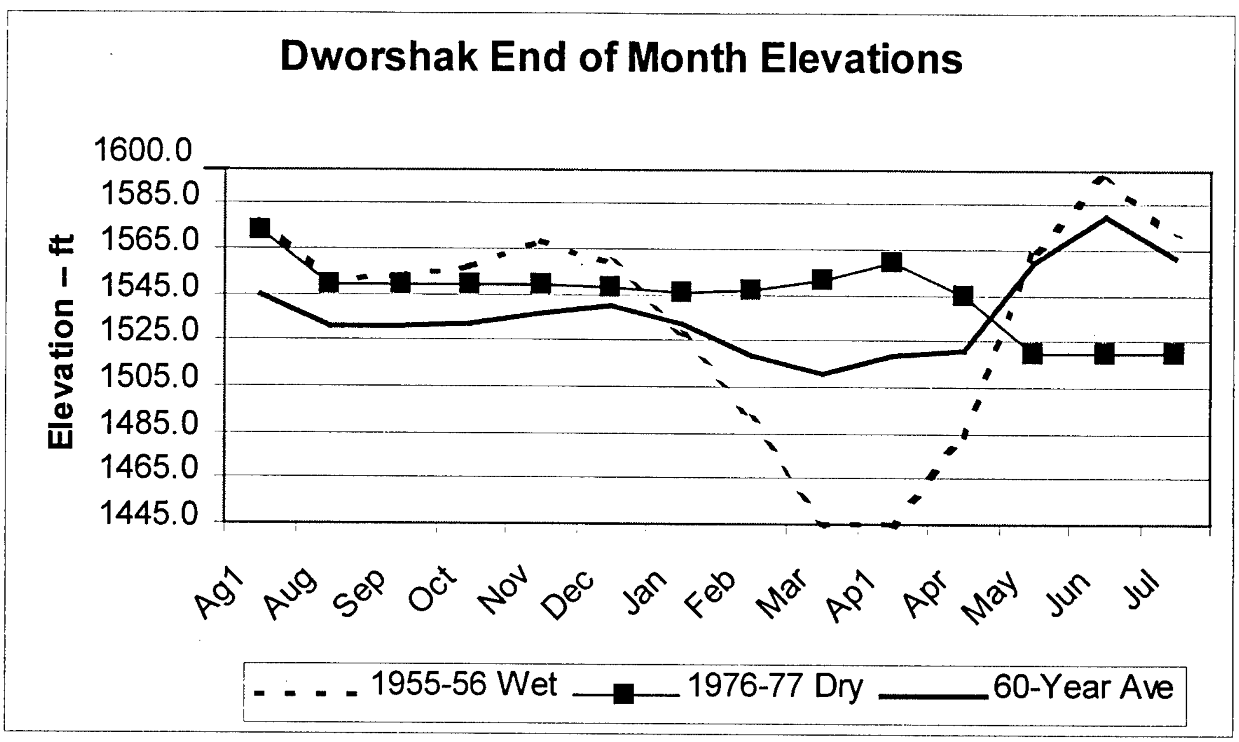
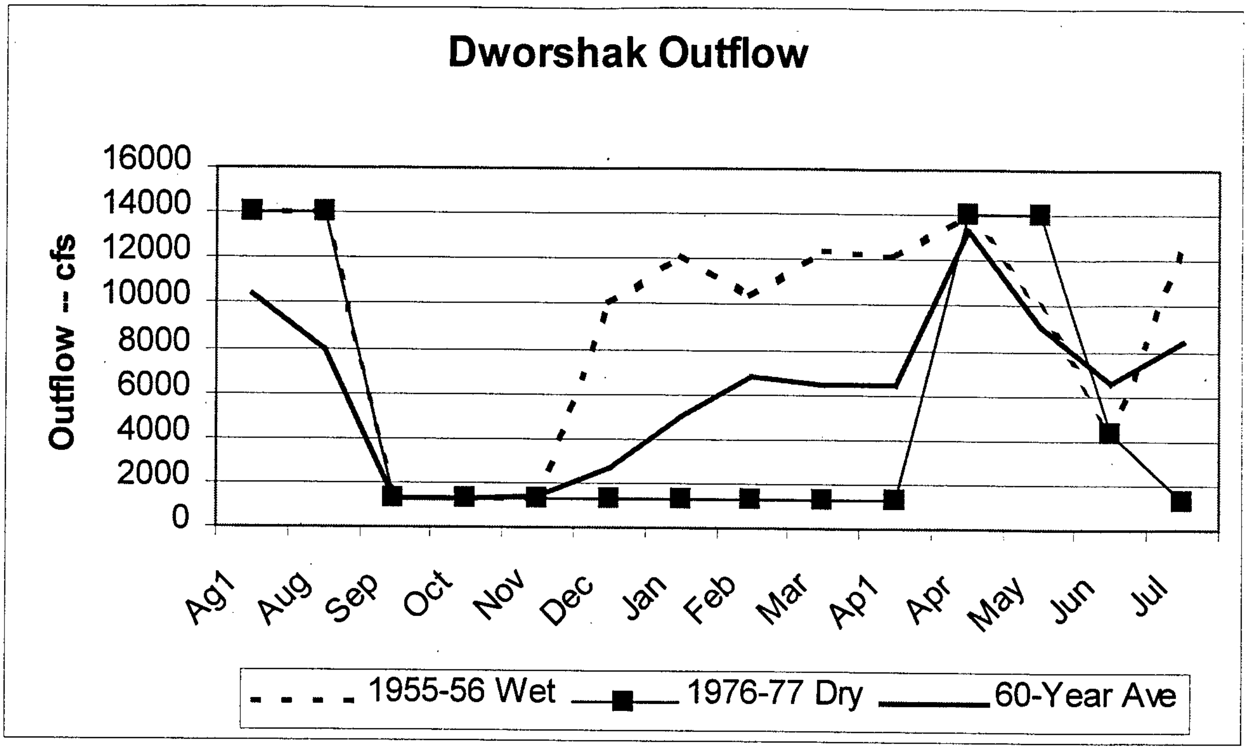



Figure B-6 Alternative B1 Graphs (continued)



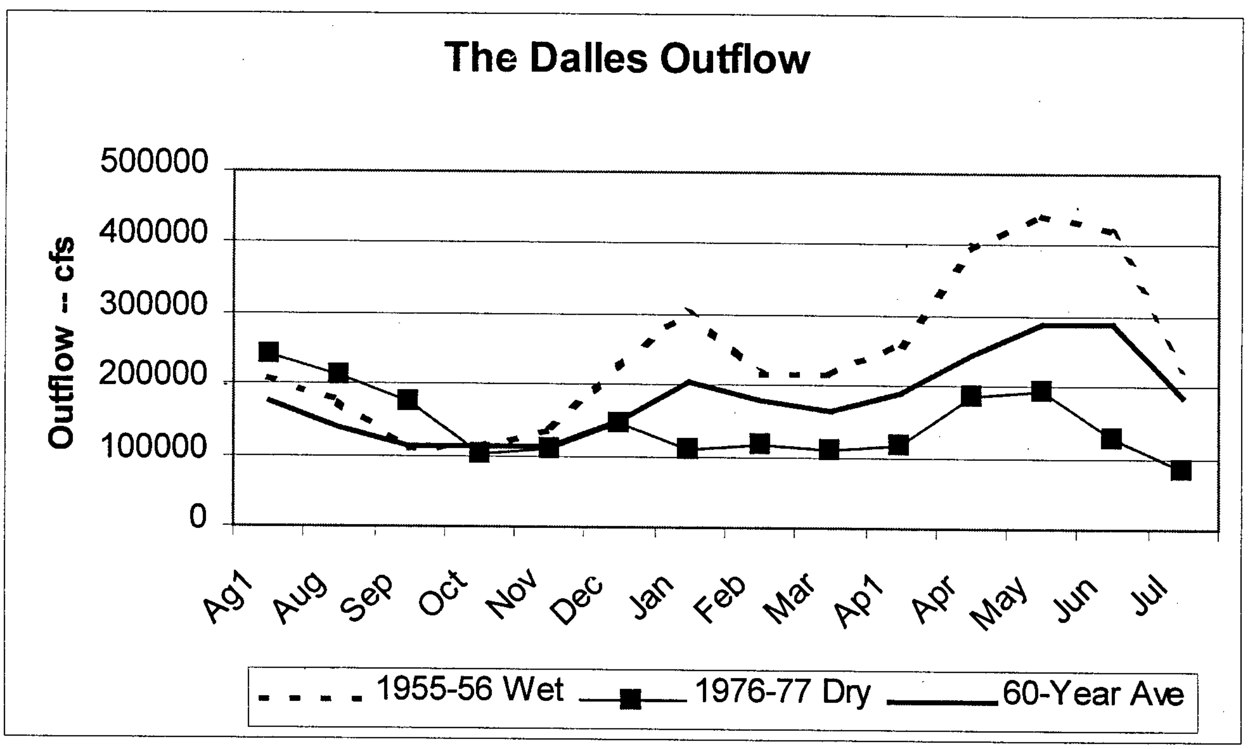
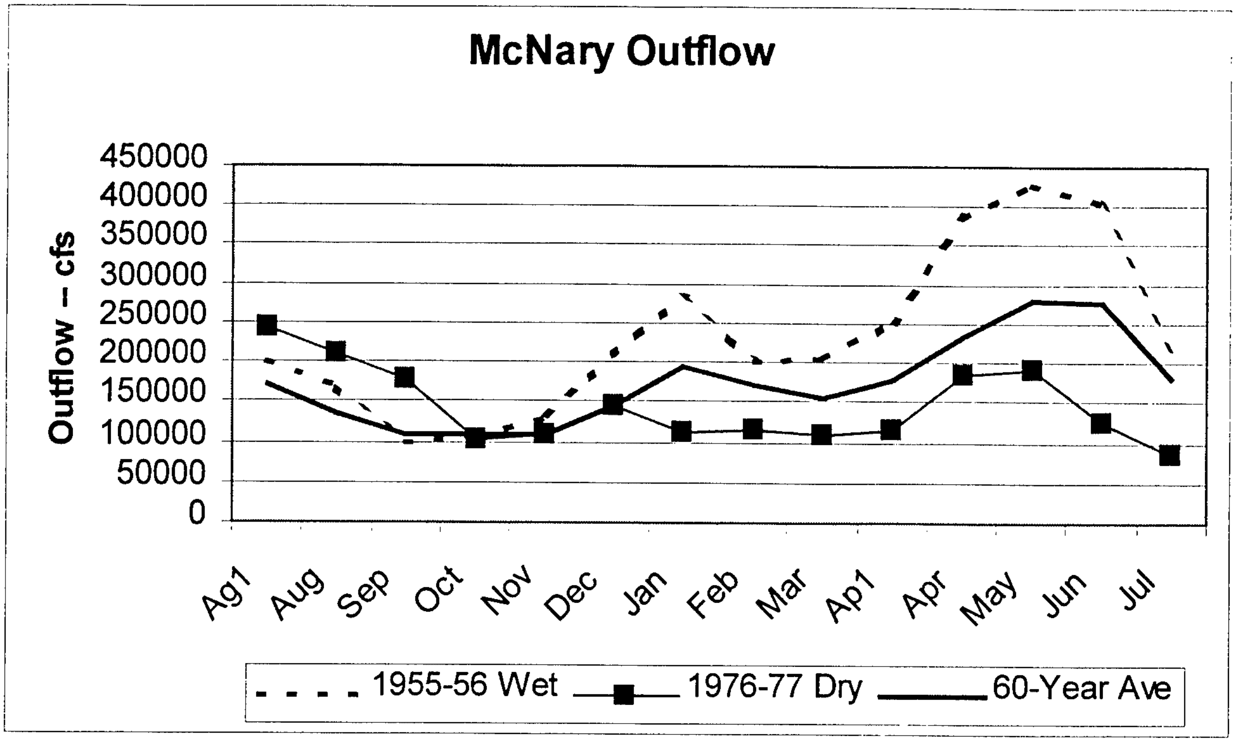



Figure B-6 Alternative B1 Graphs (continued)



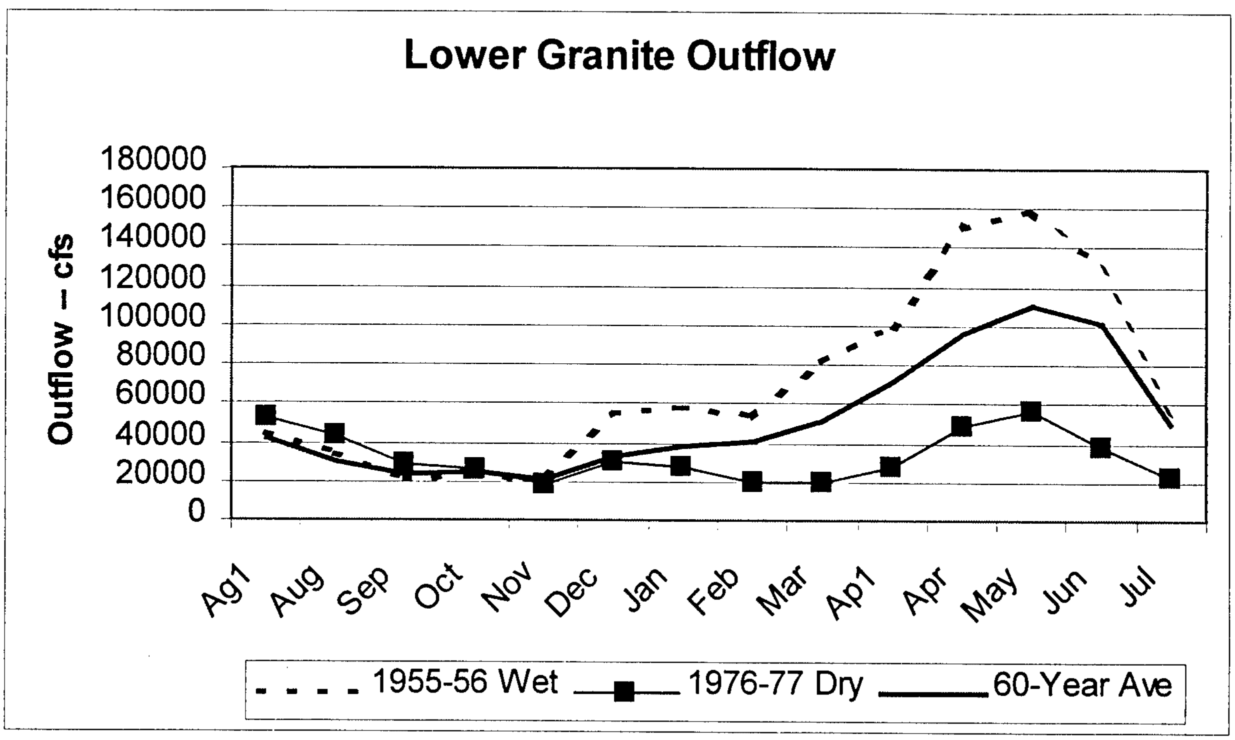
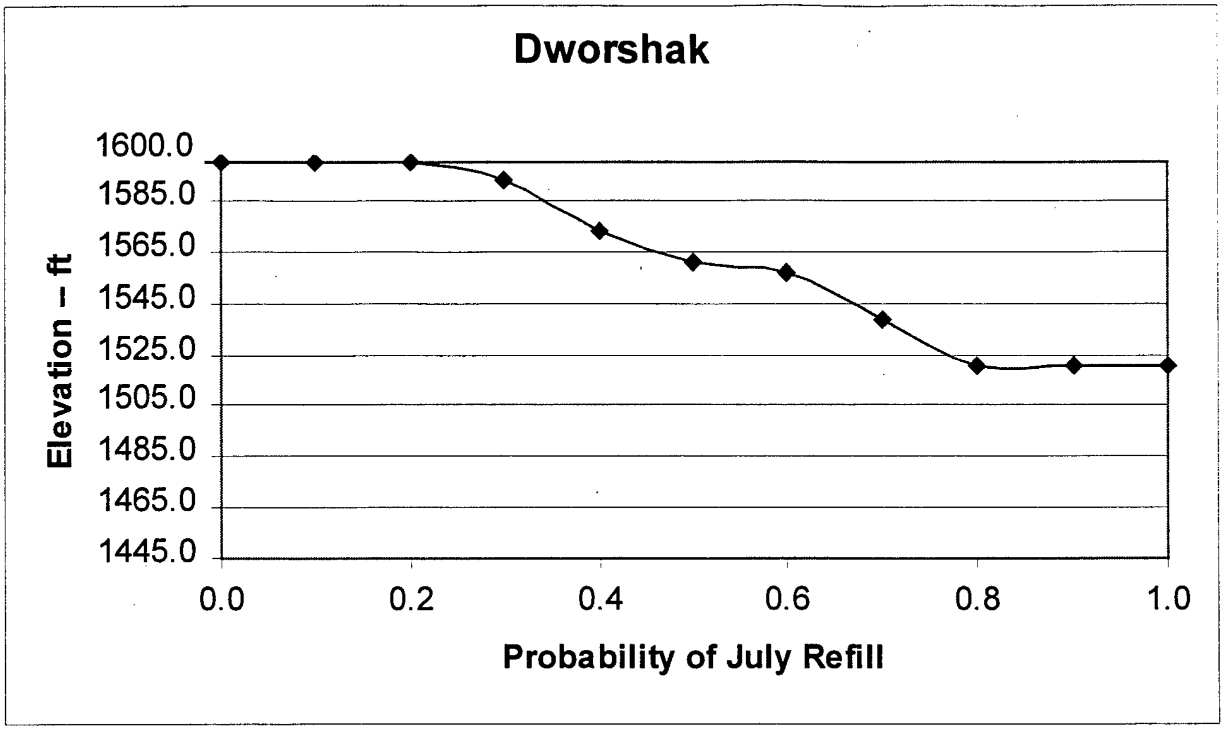



Figure B-6 Alternative B1 Graphs (continued)



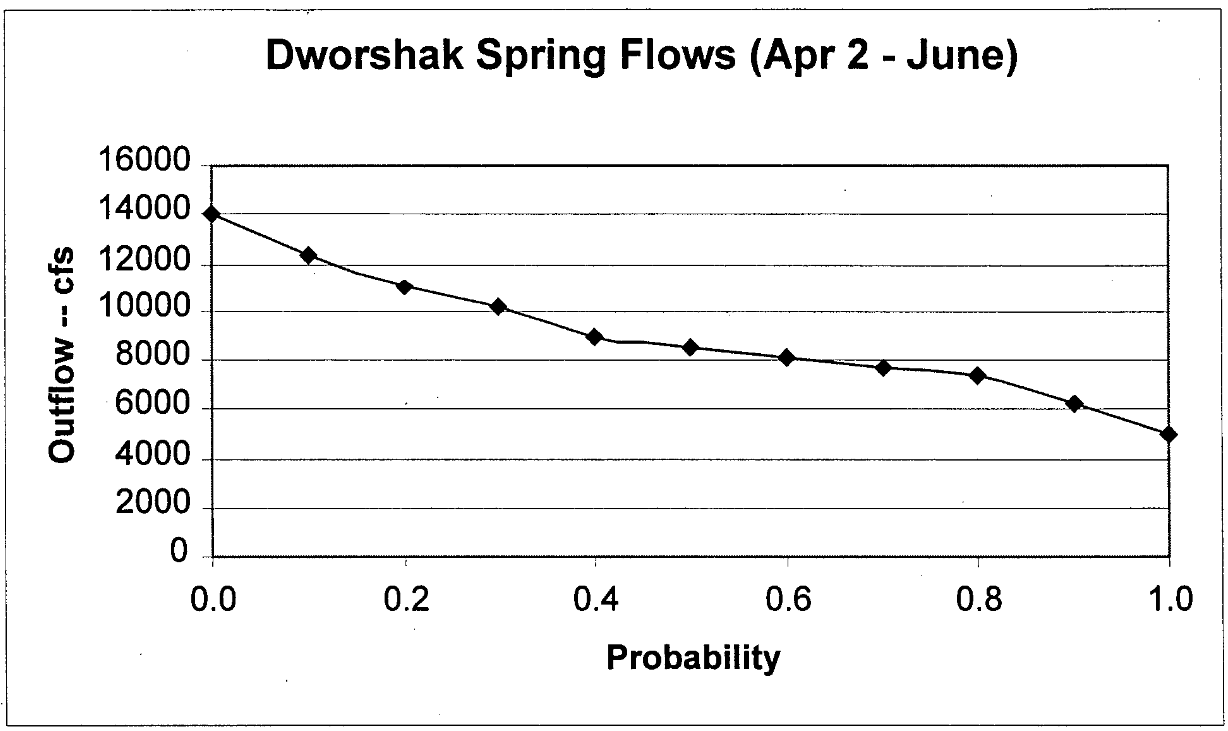
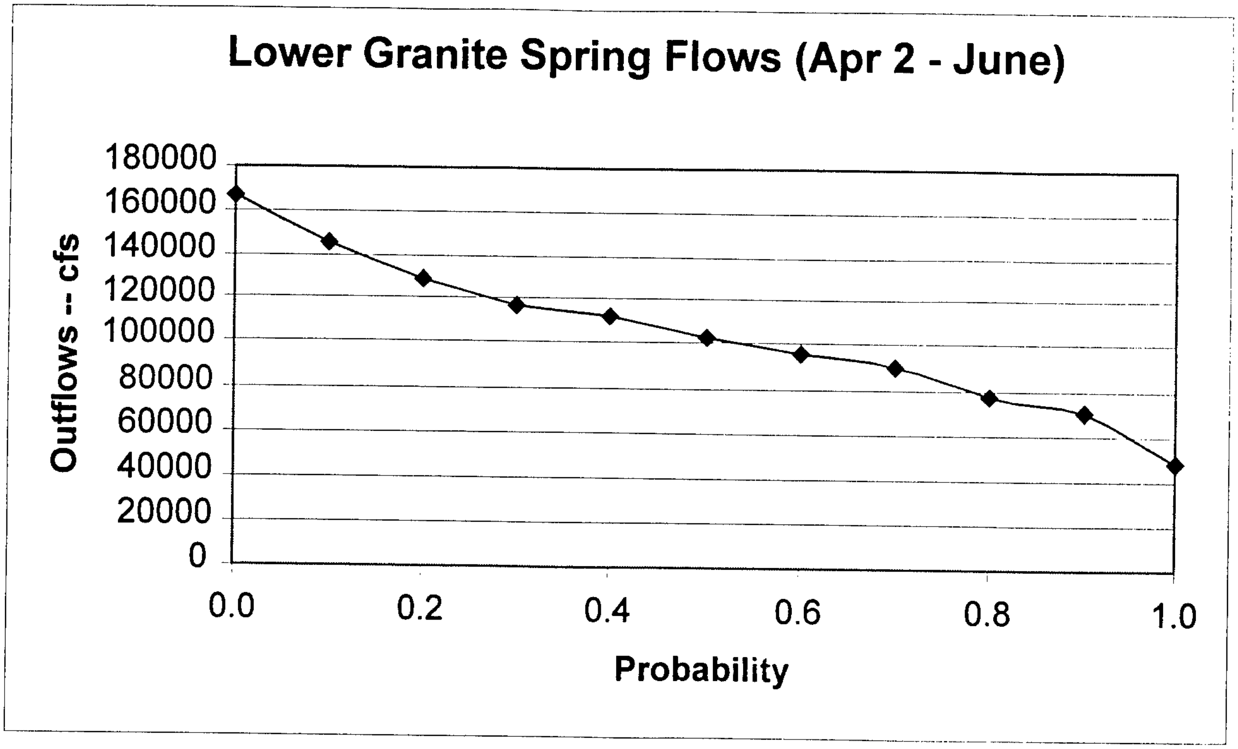



Figure B-6 Alternative B1 Graphs (continued)



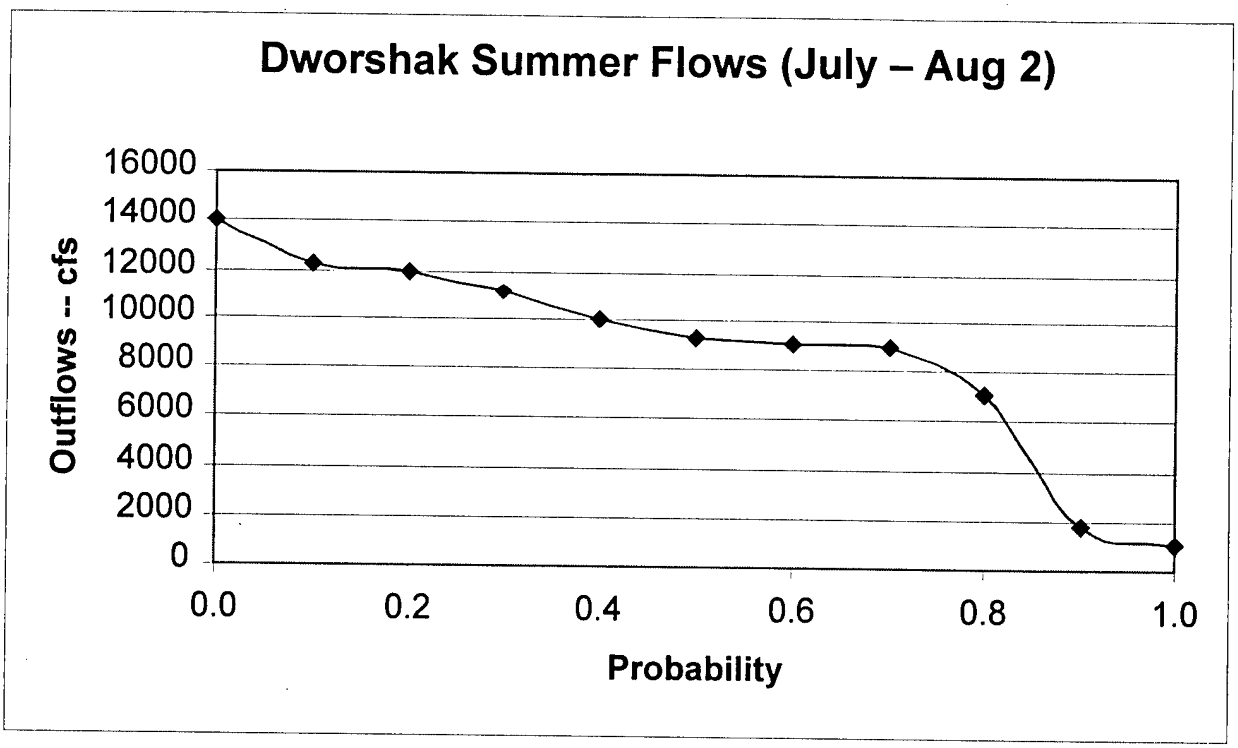



Figure B-6 Alternative B1 Graphs (continued)

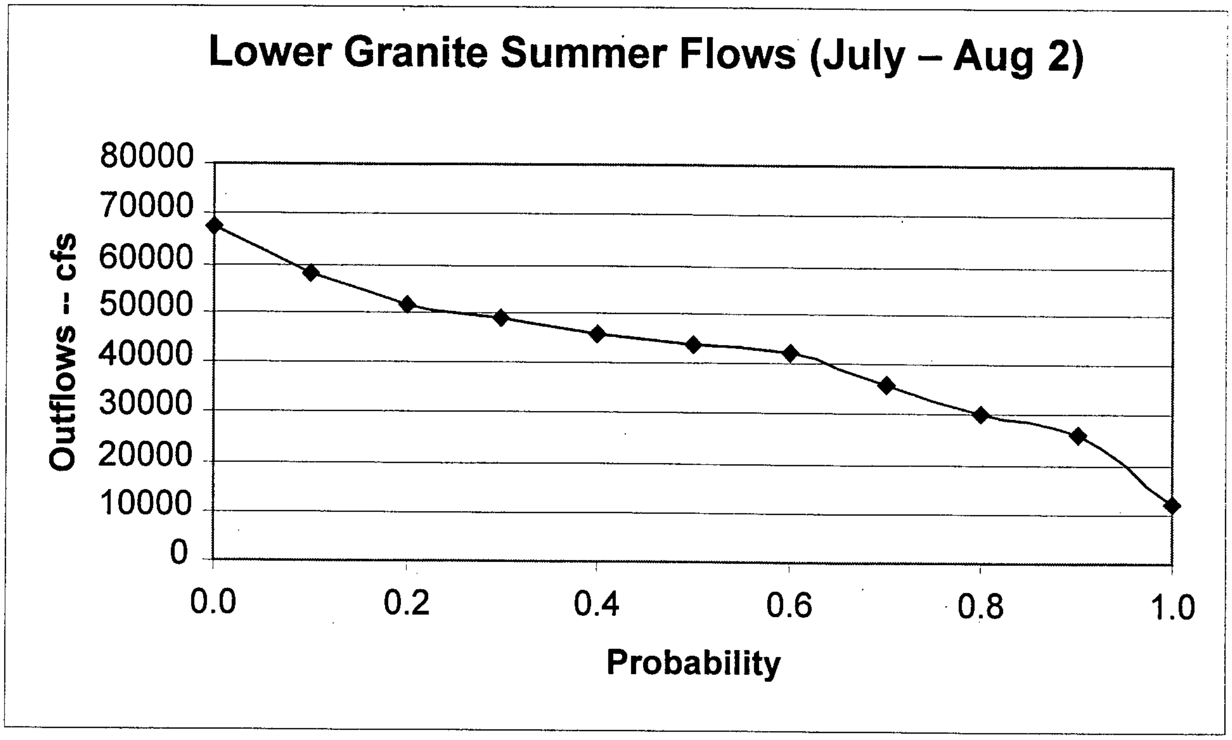
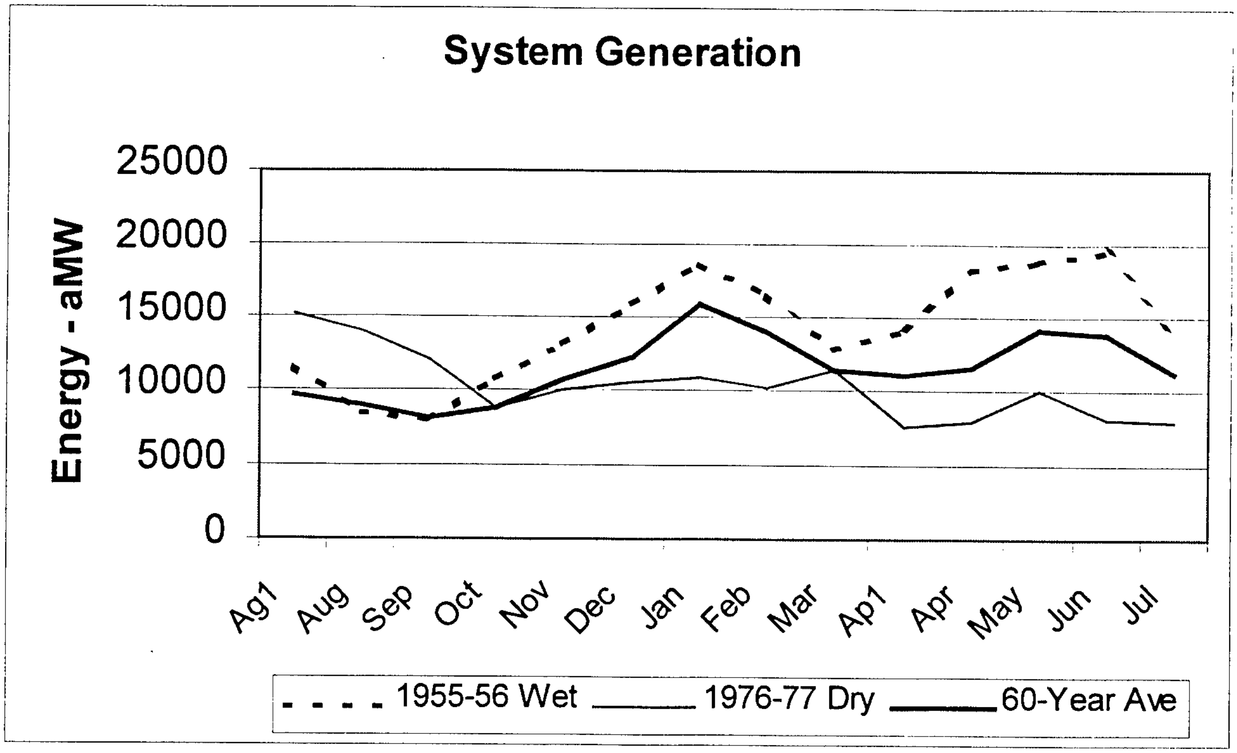


Figure B-3 Alternative B2 Graphs



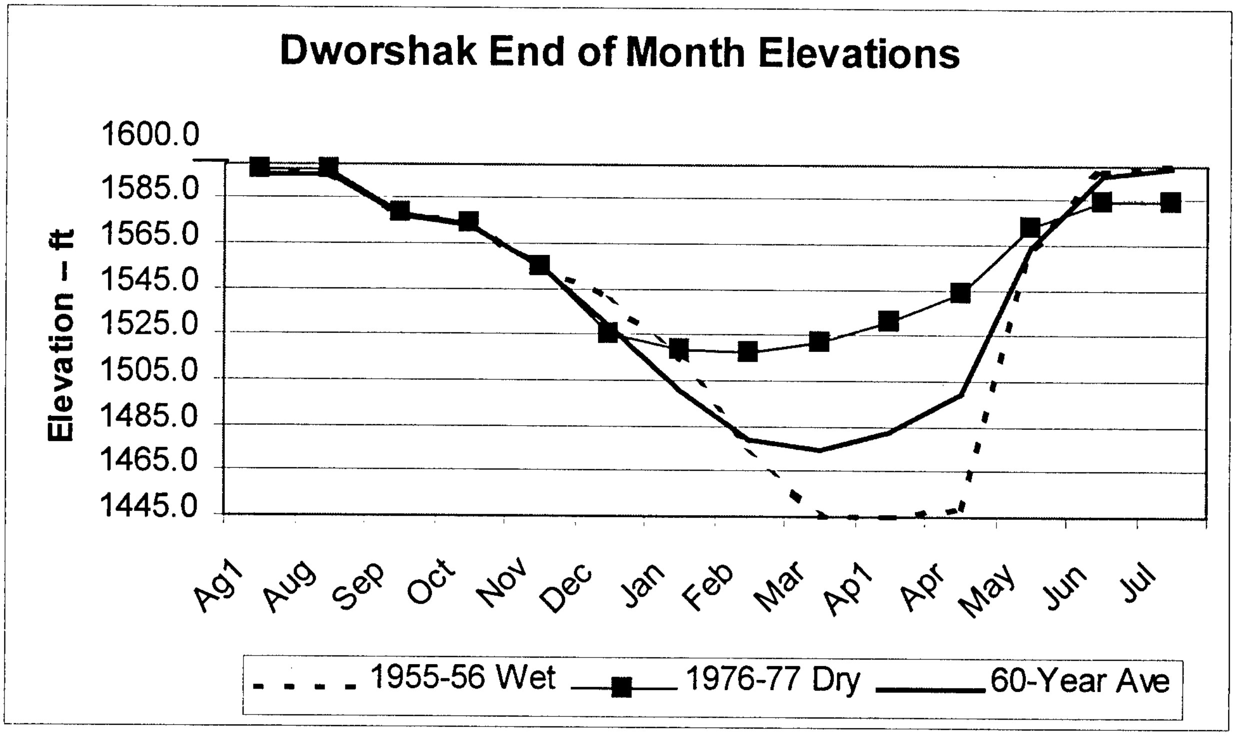
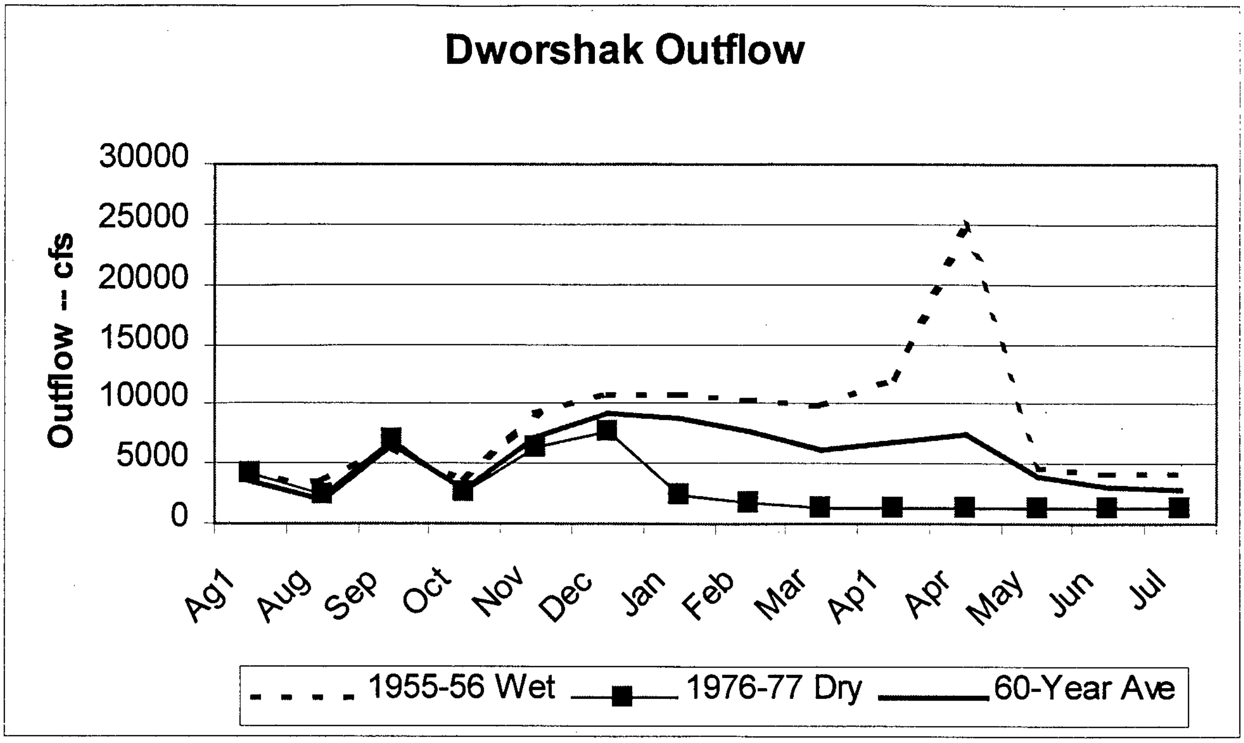



Figure B-7 Alternative B2 Graphs (continued)



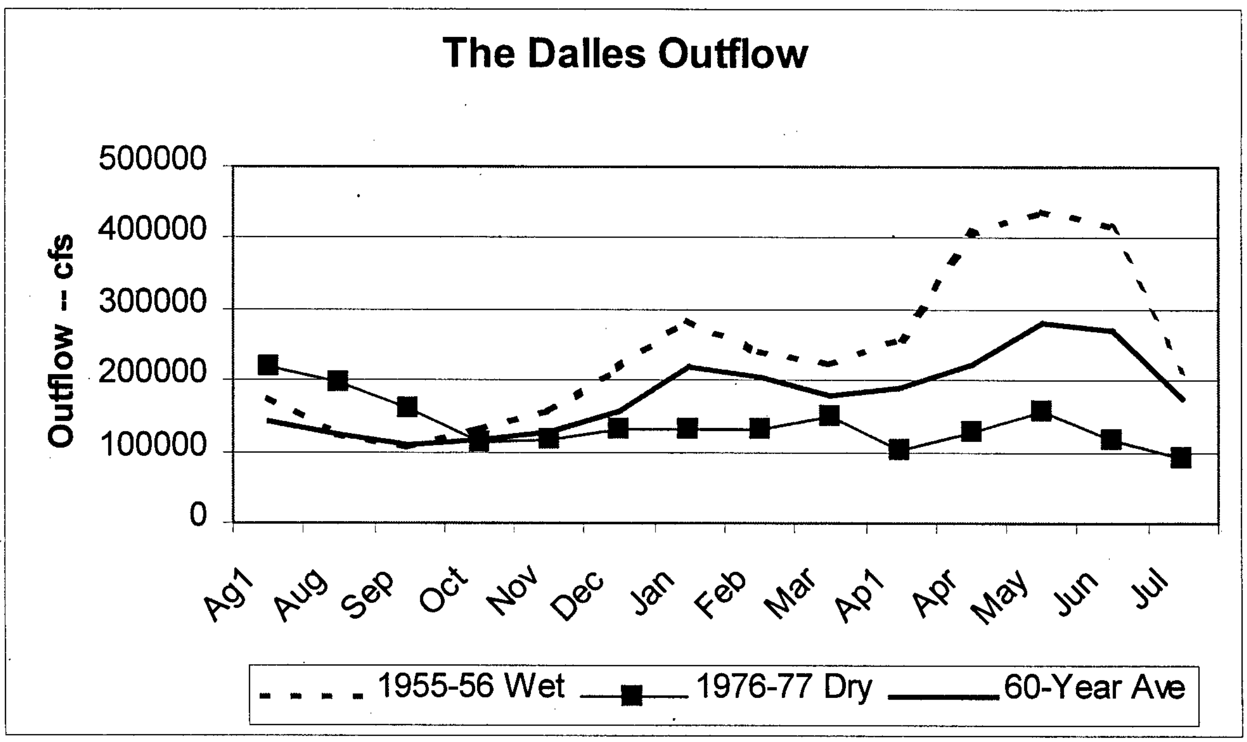
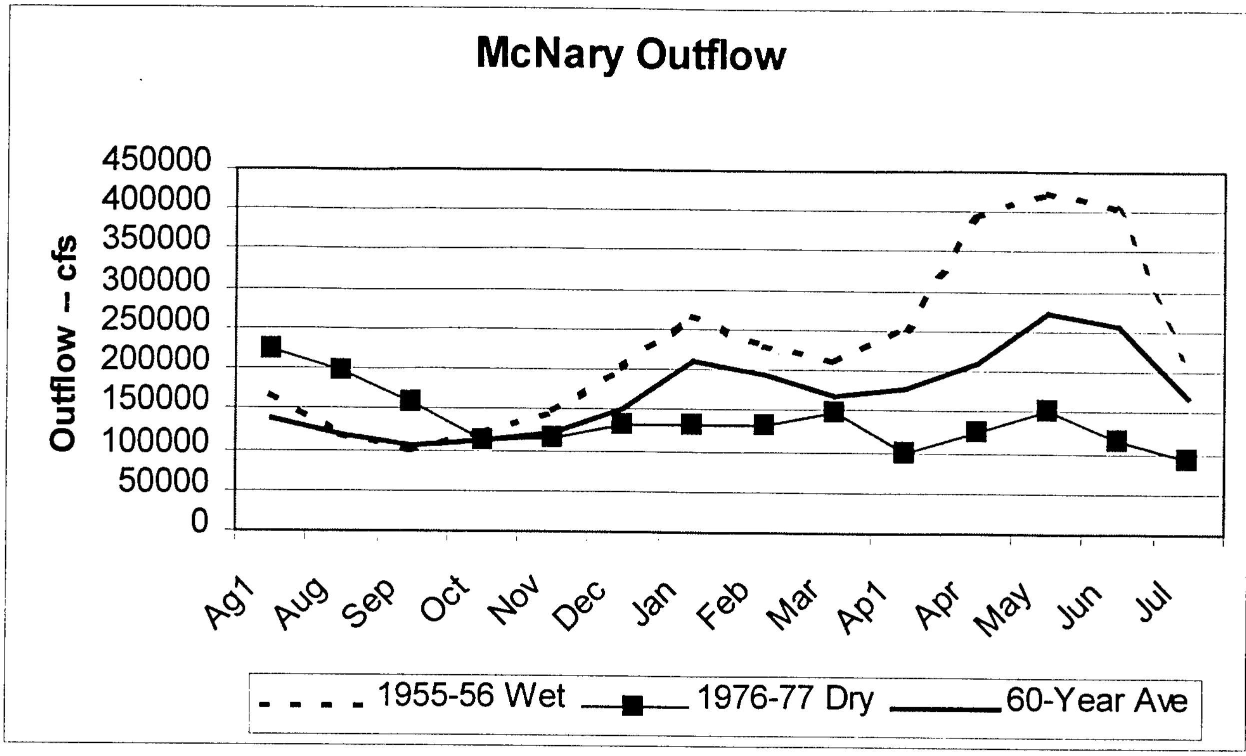



Figure B-7 Alternative B2 Graphs (continued)



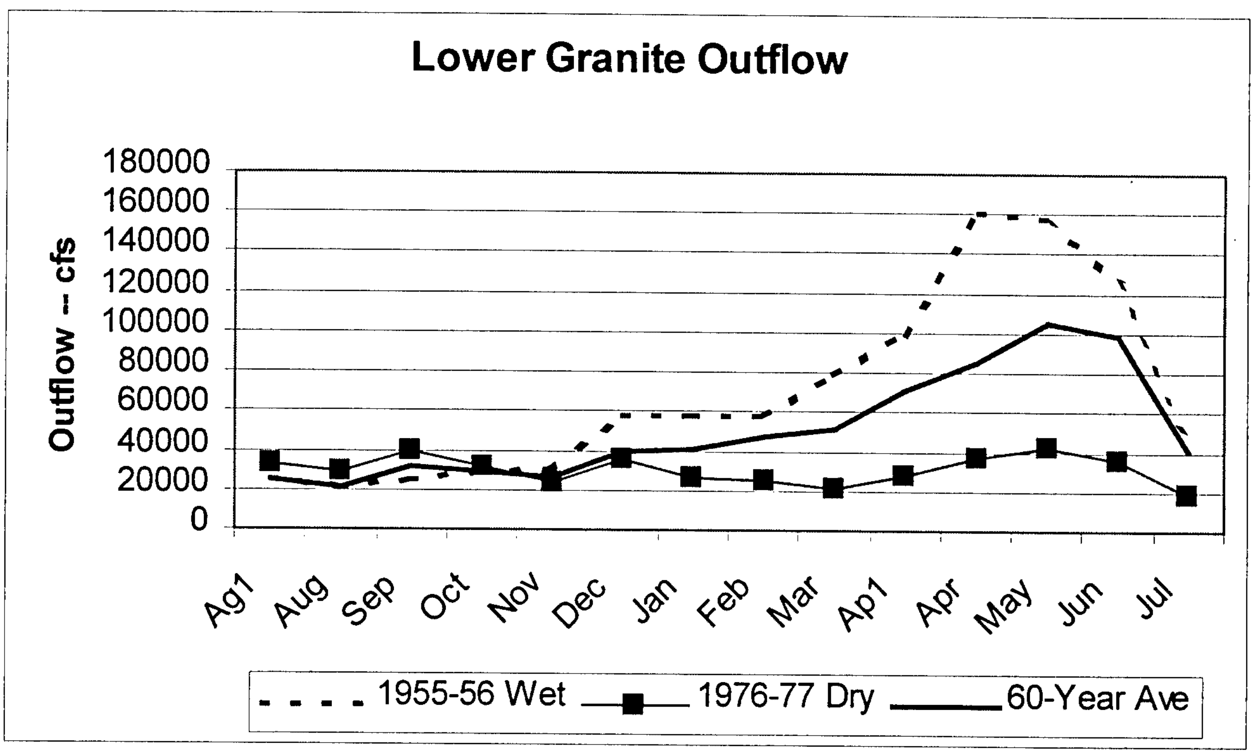
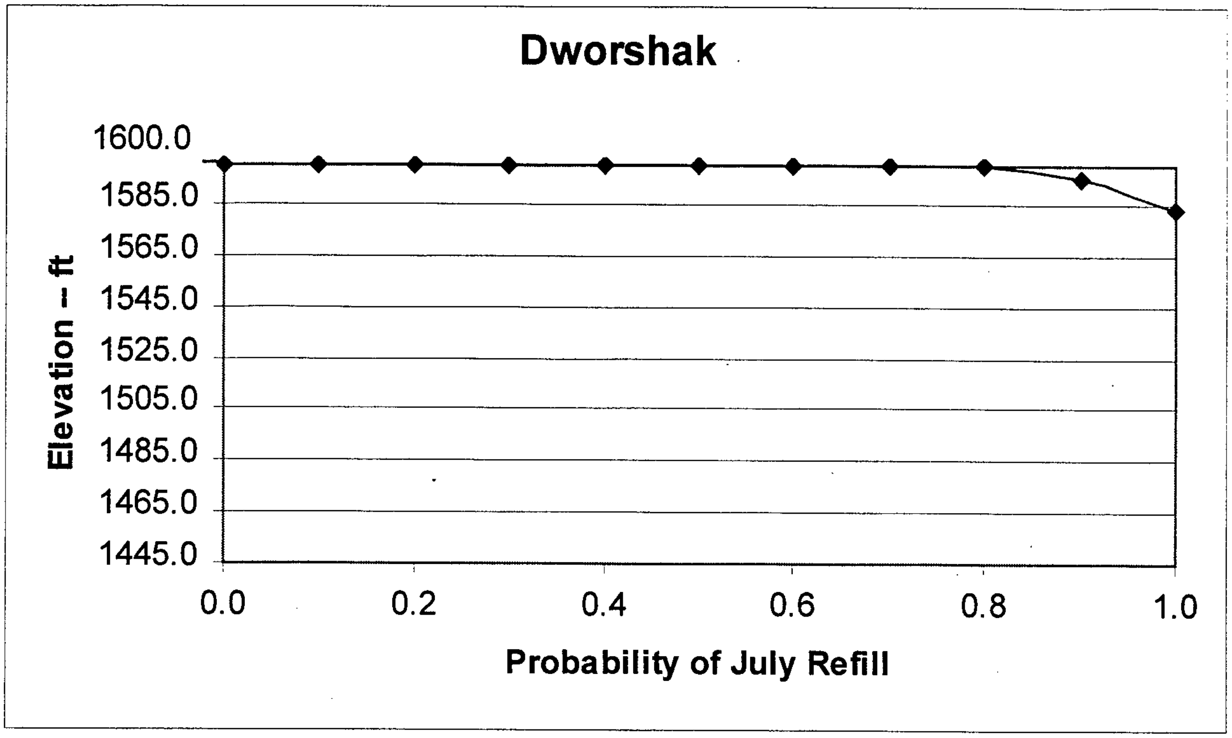



Figure B-7 Alternative B2 Graphs (continued)



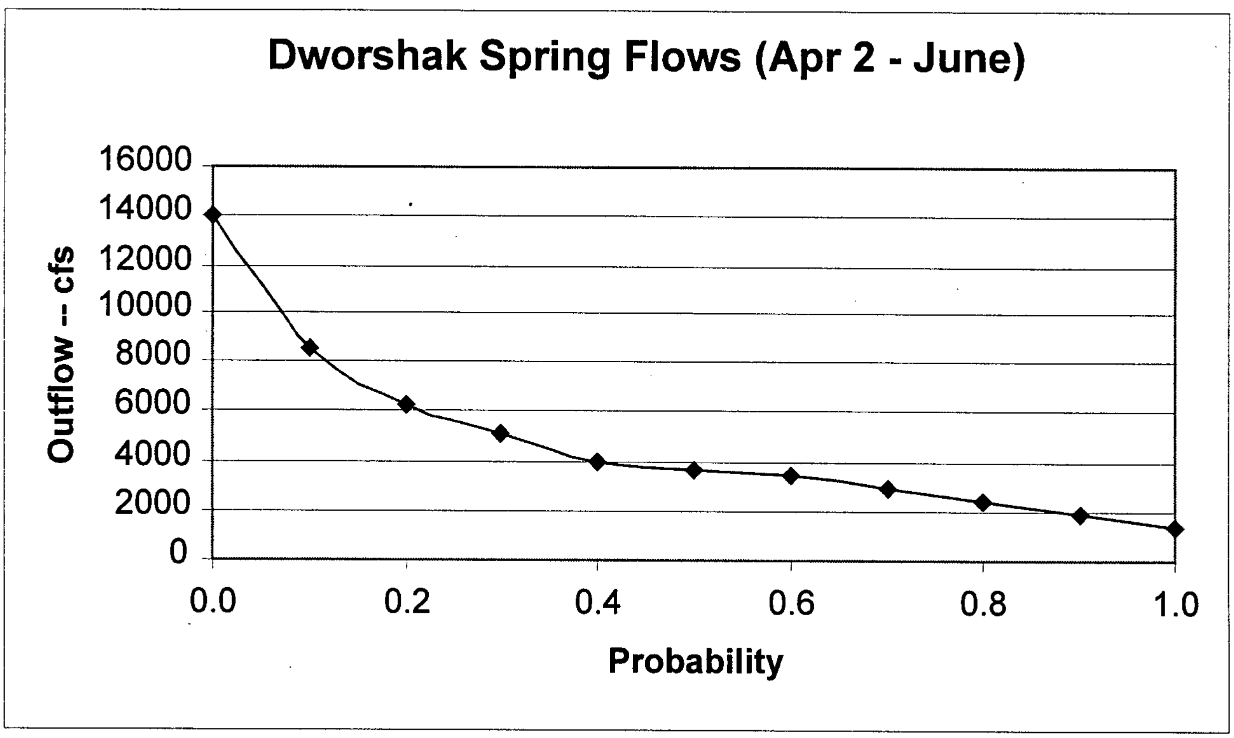
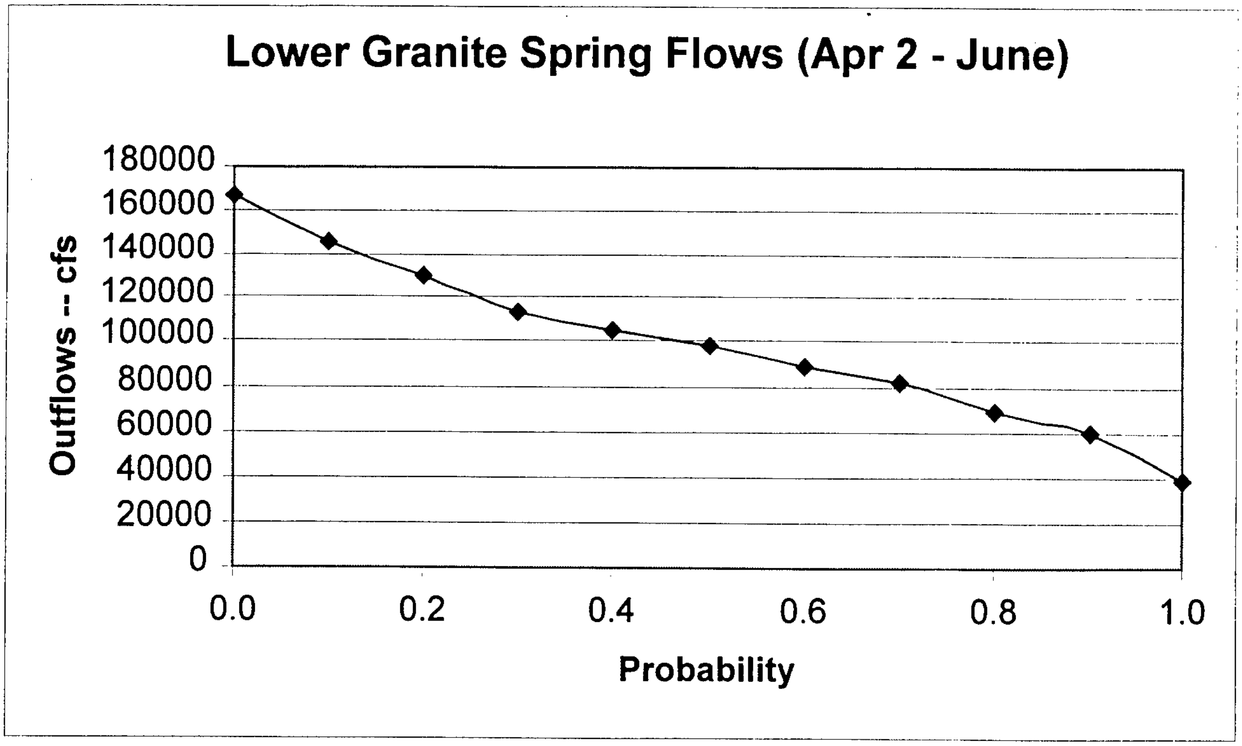



Figure B-7 Alternative B2 Graphs (continued)



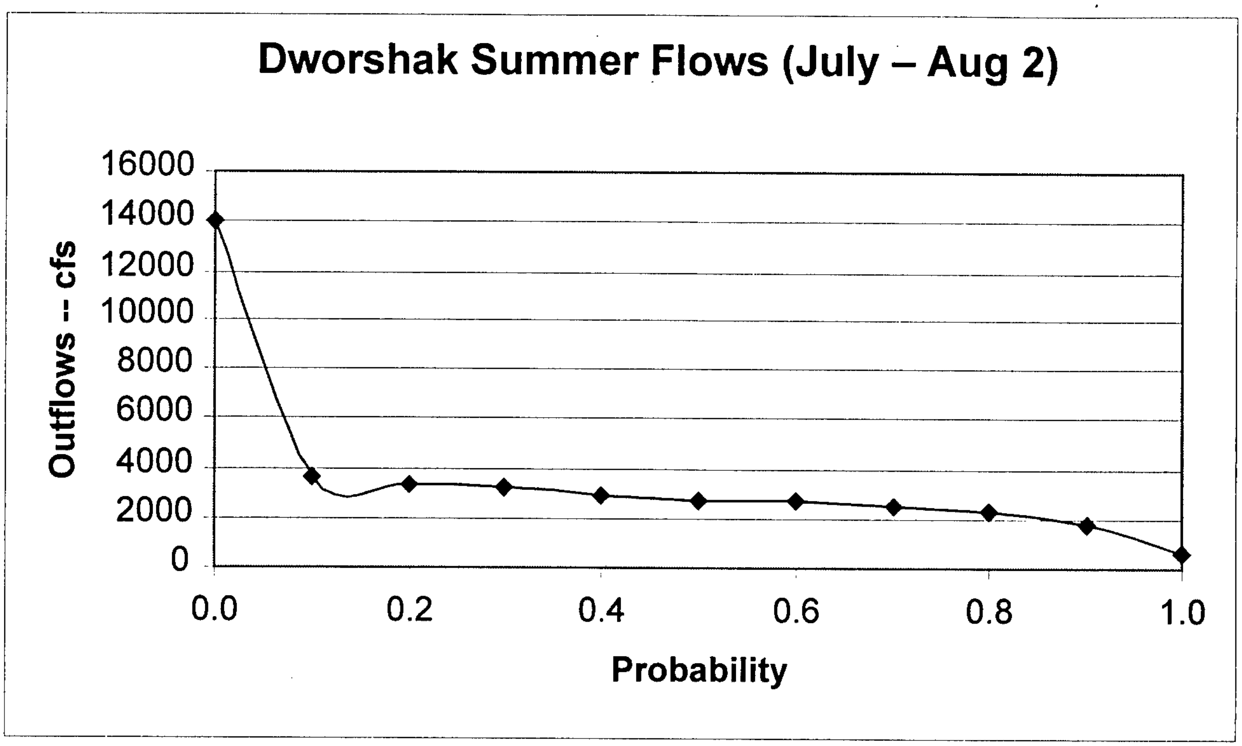



Figure B-7 Alternative B2 Graphs (continued)

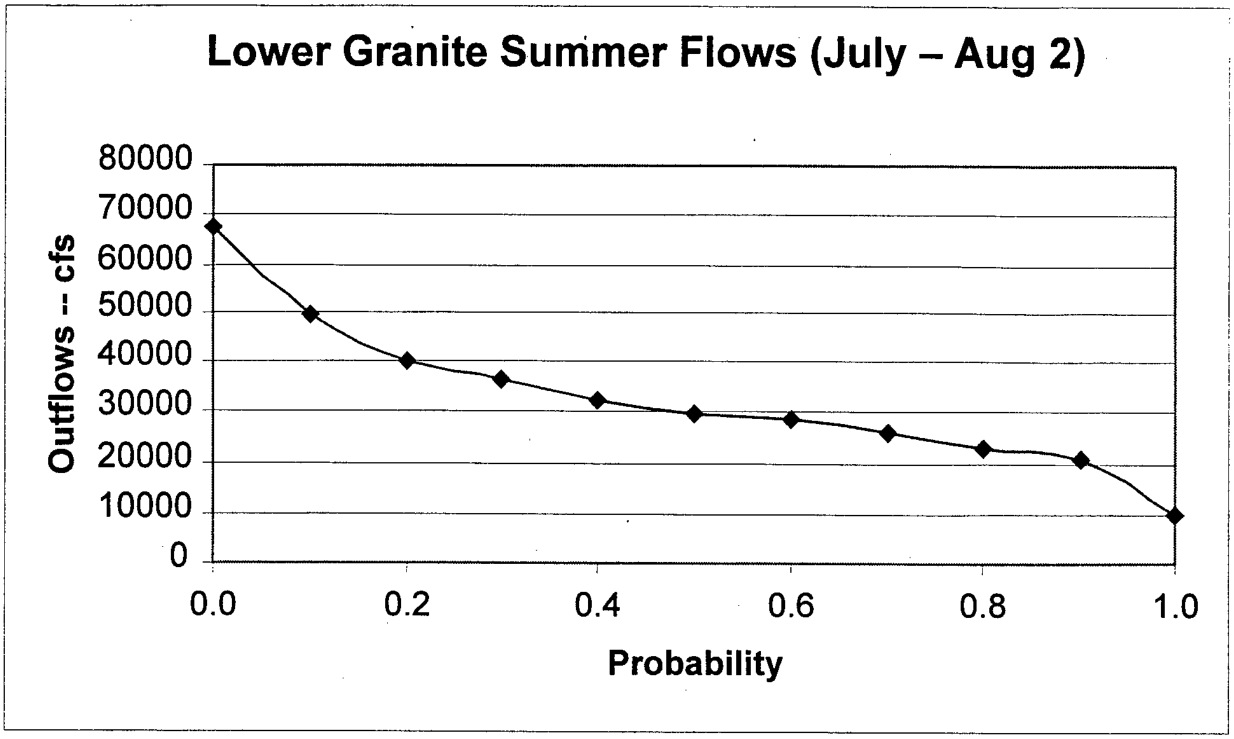
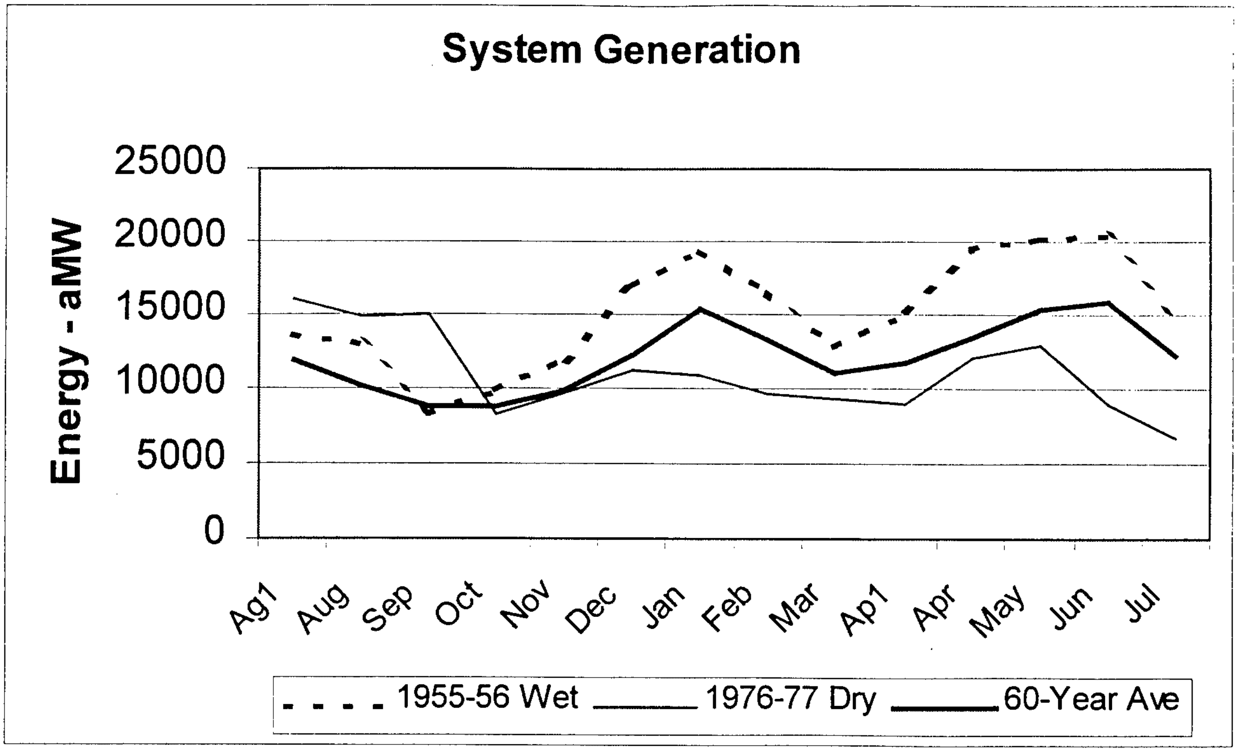


**Figure B-8 Alternative C1 Graphs**



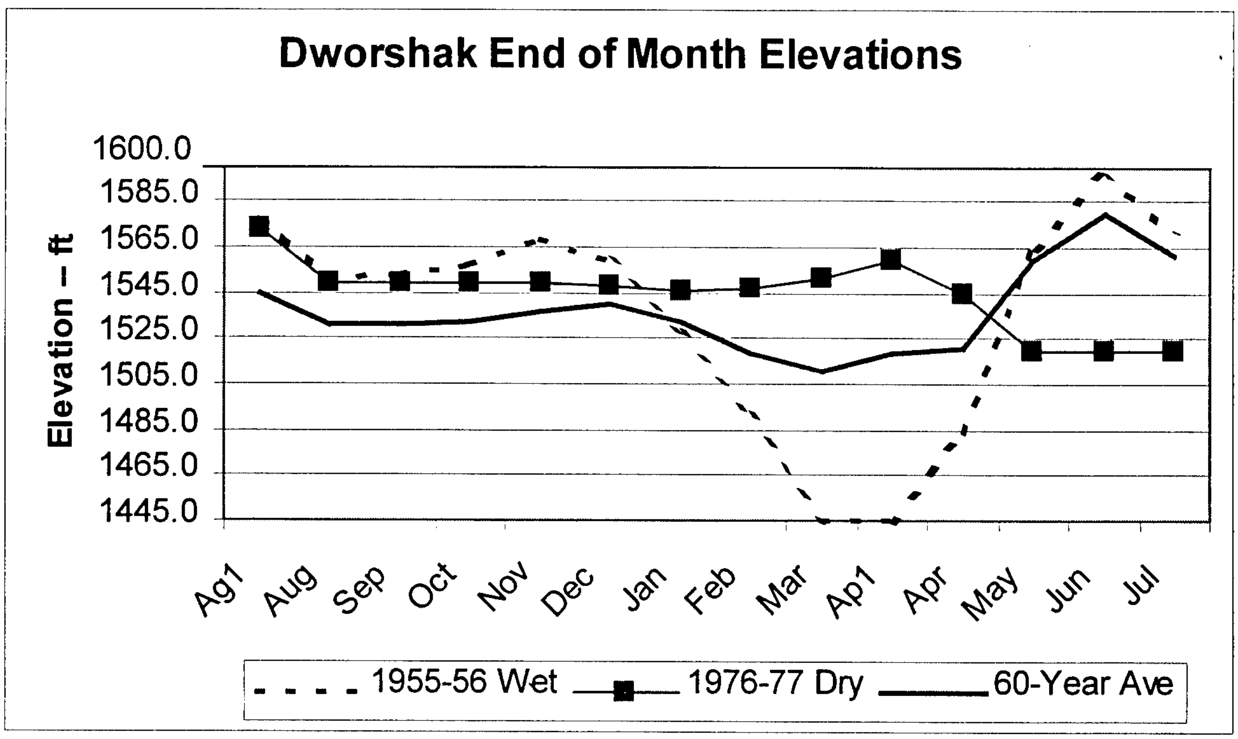
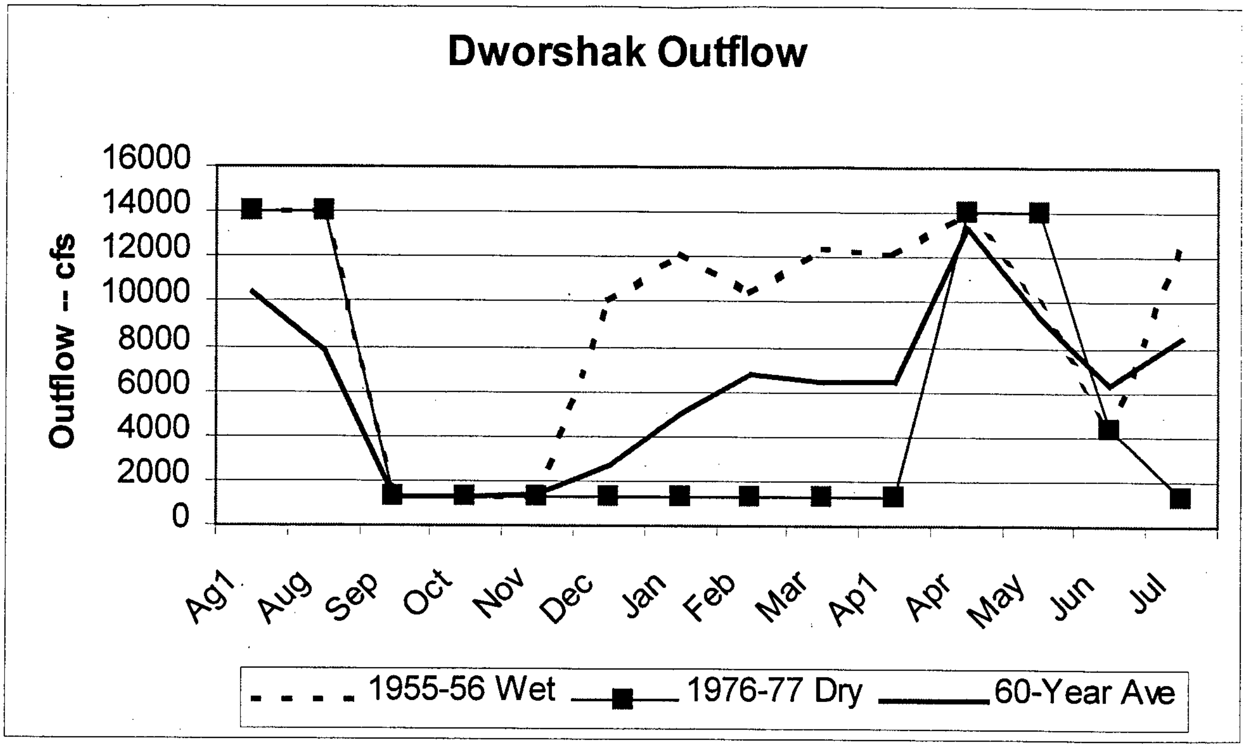



Figure B-8 Alternative C1 Graphs (continued)



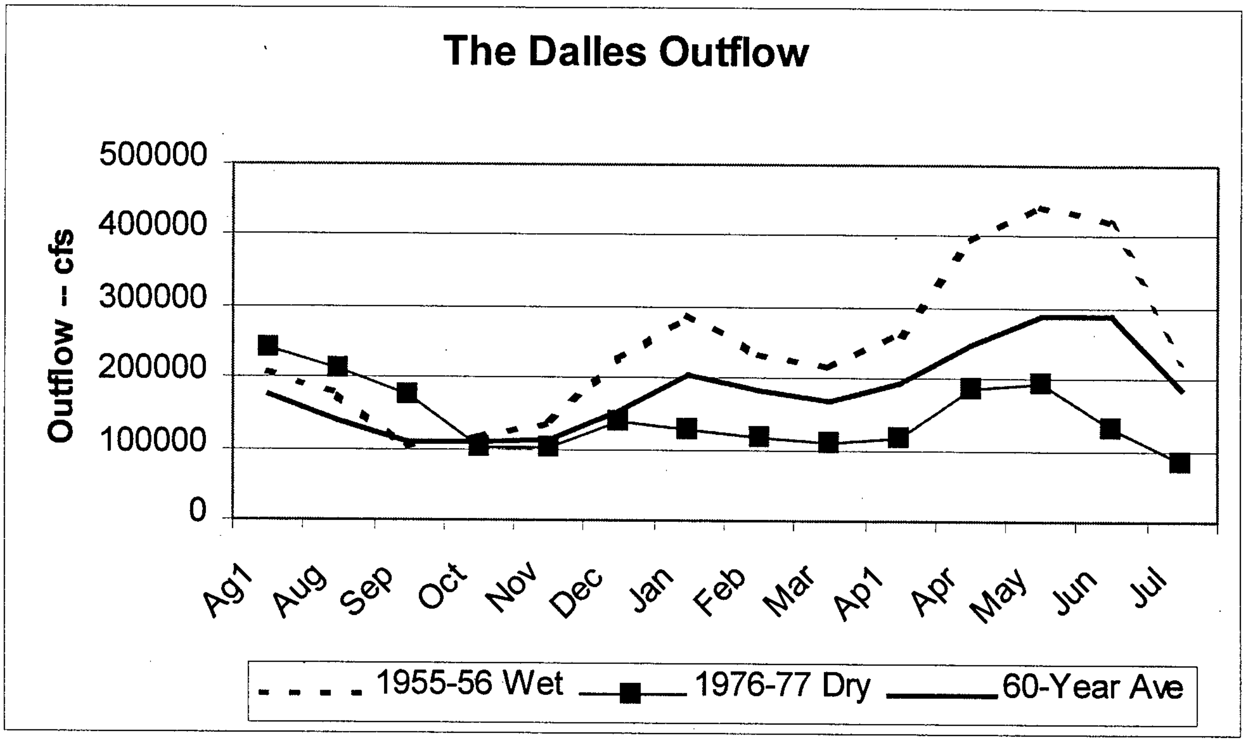
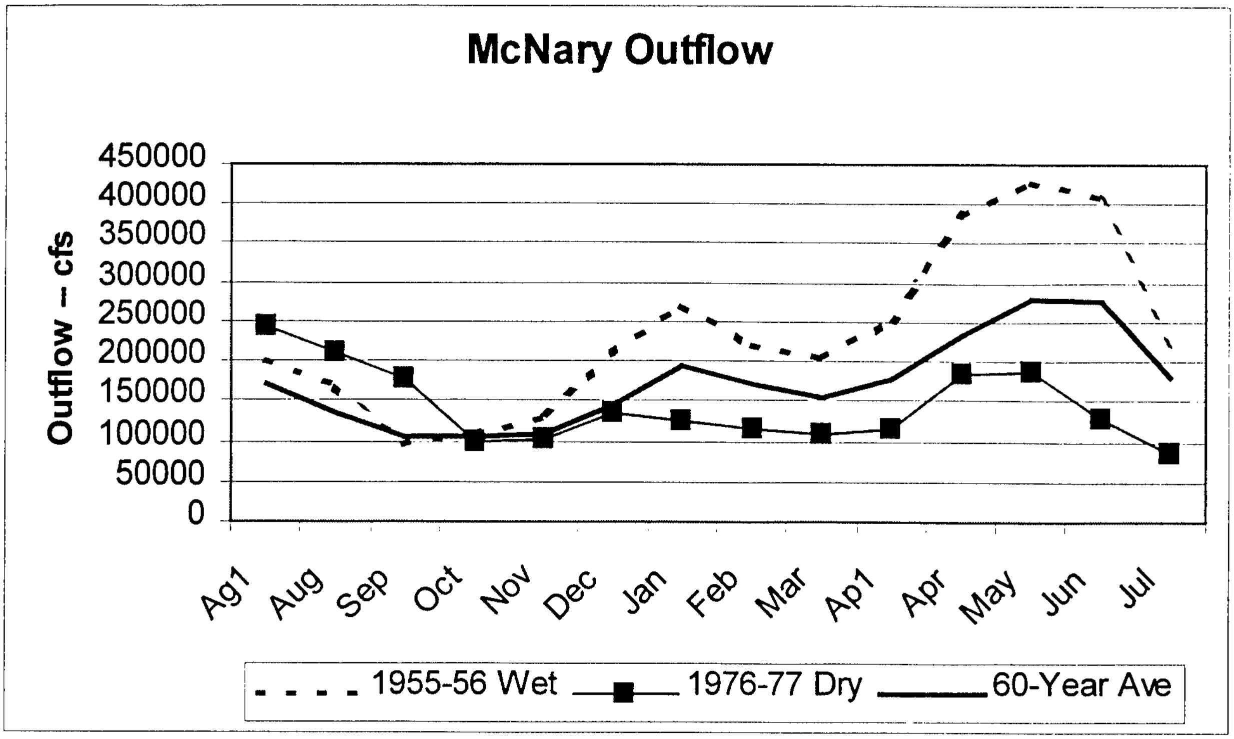



Figure B-8 Alternative C1 Graphs (continued)



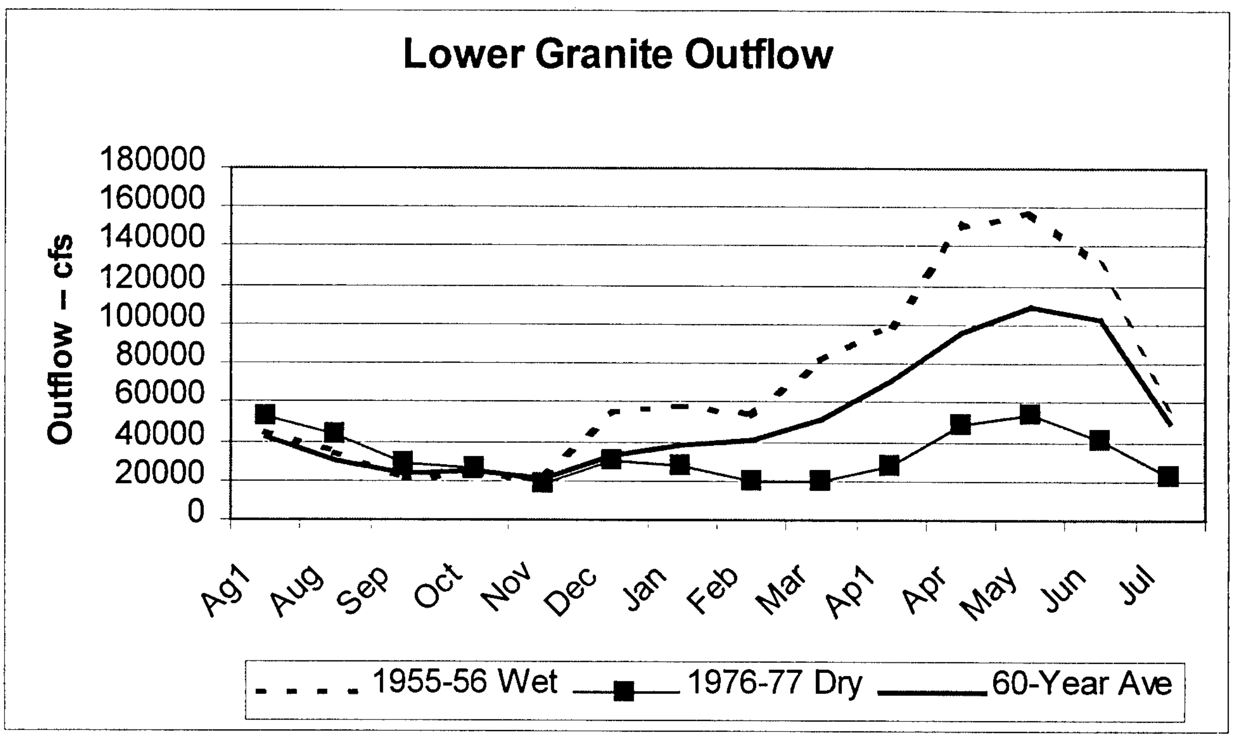
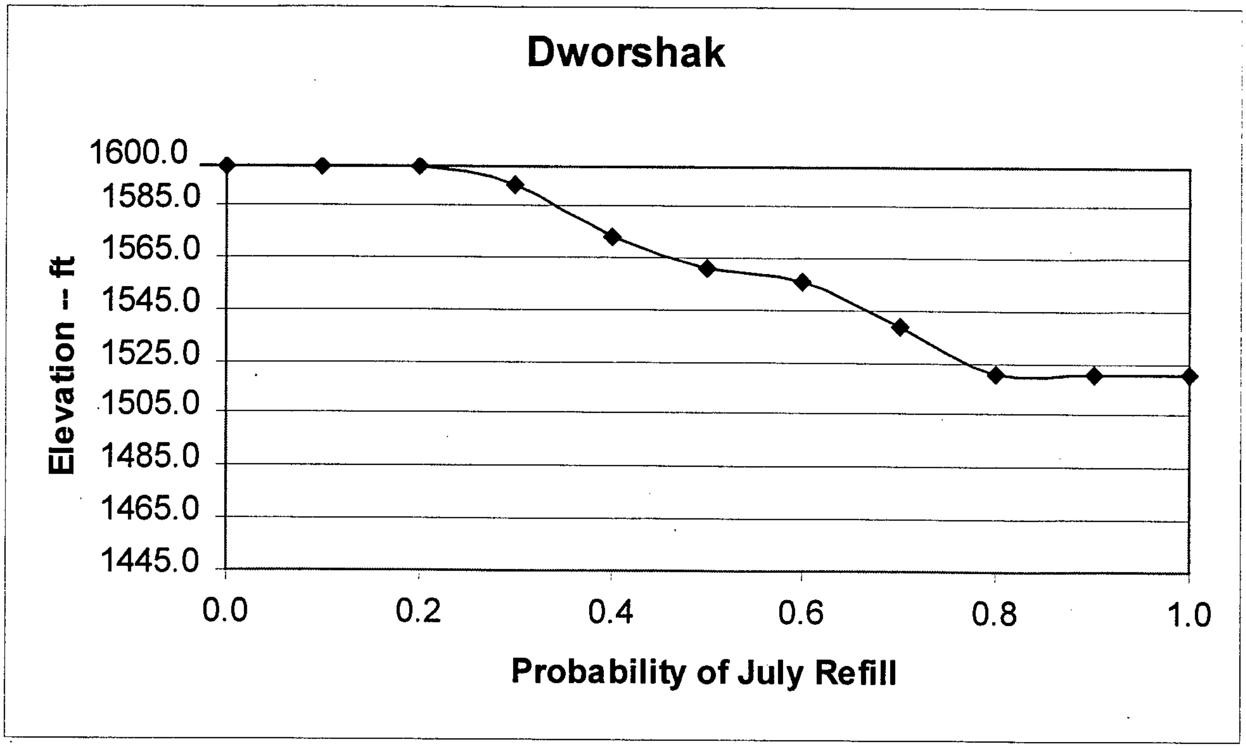



Figure B-8 Alternative C1 Graphs (continued)



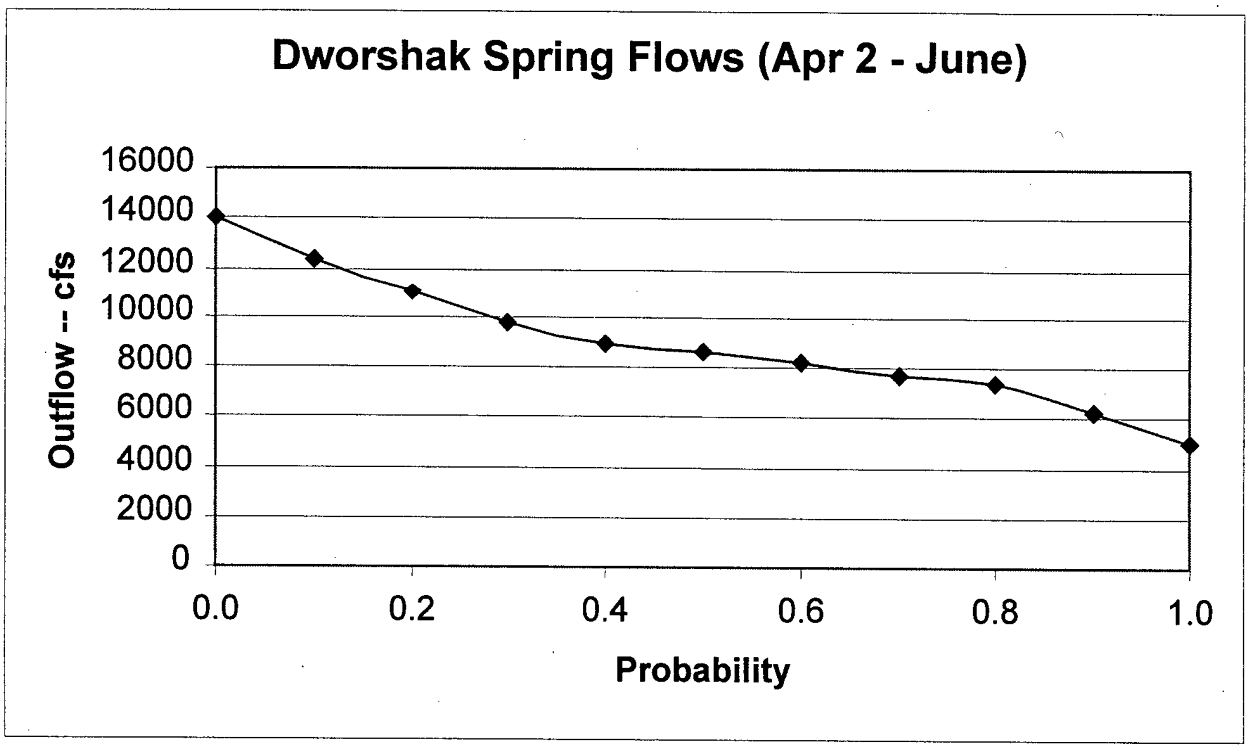
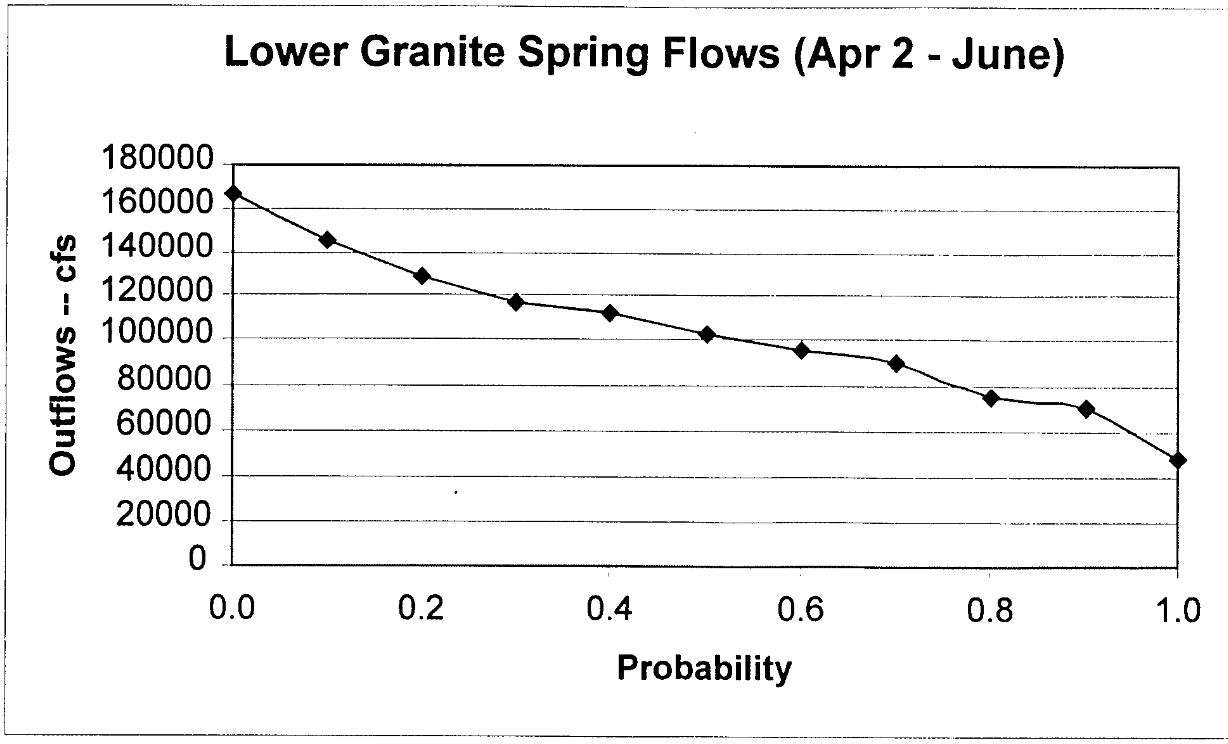



Figure B-8 Alternative C1 Graphs (continued)



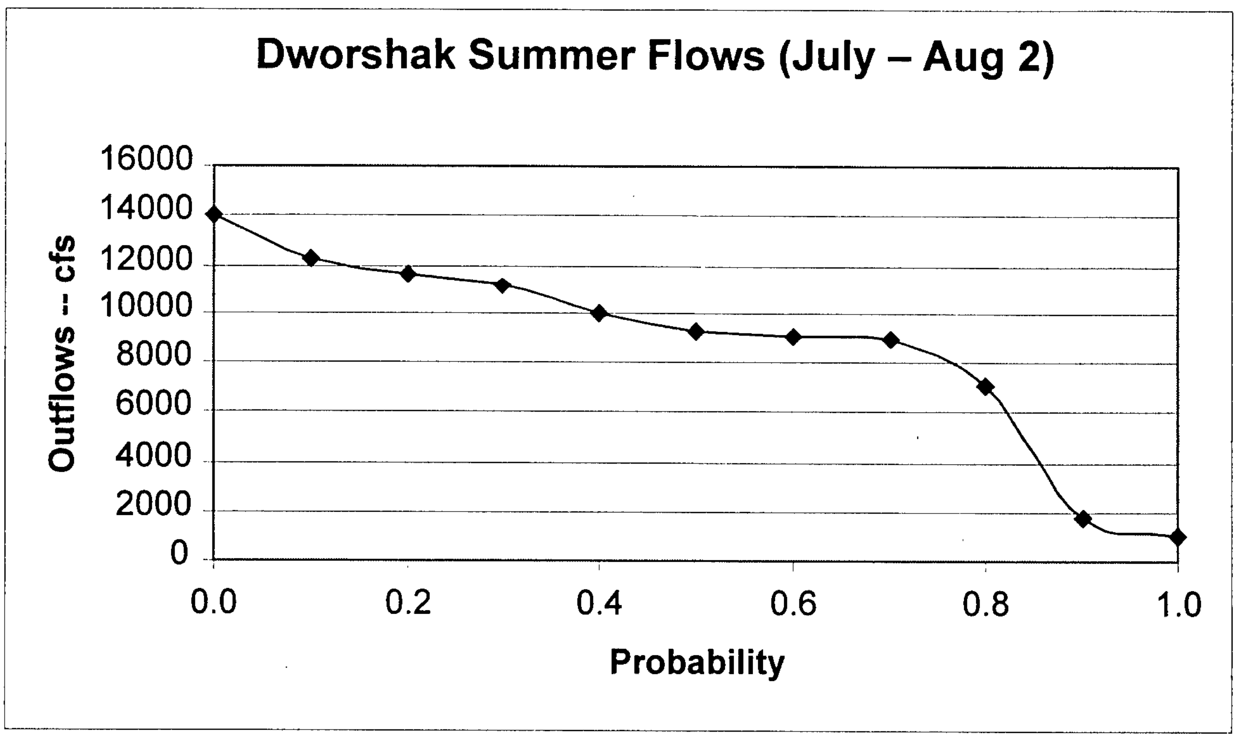



Figure B-8 Alternative C1 Graphs (continued)

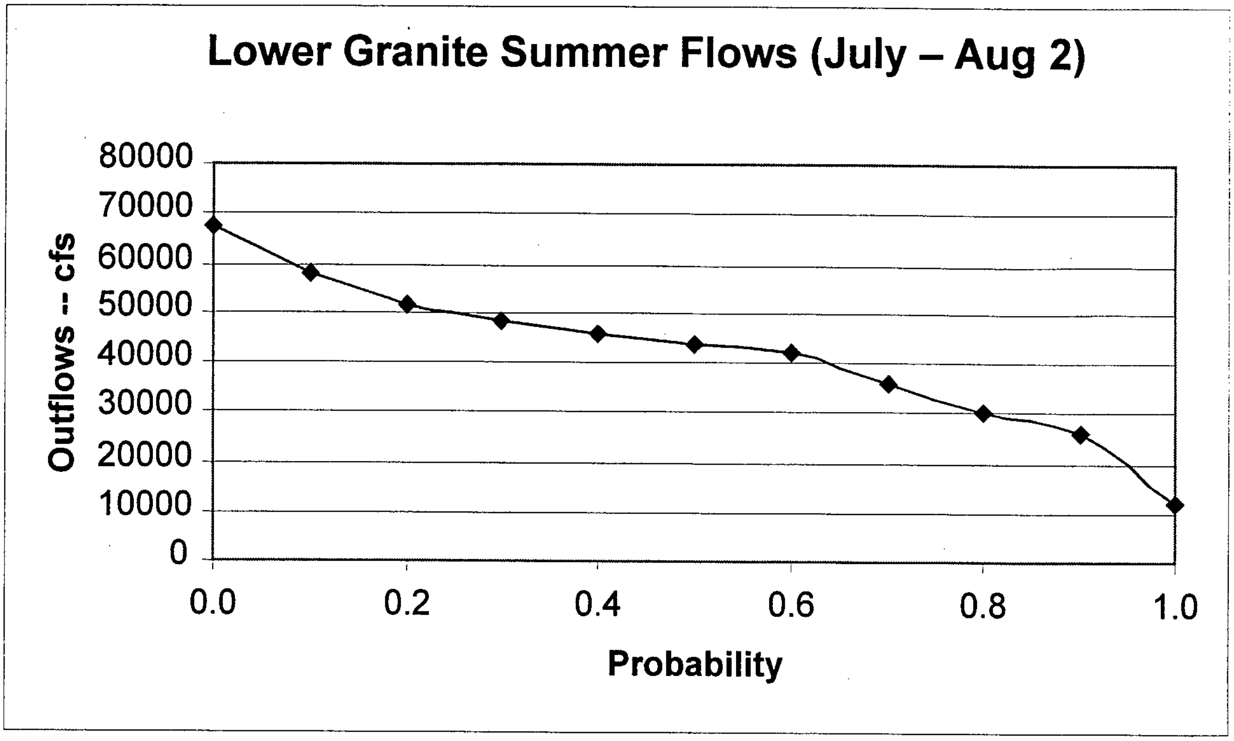
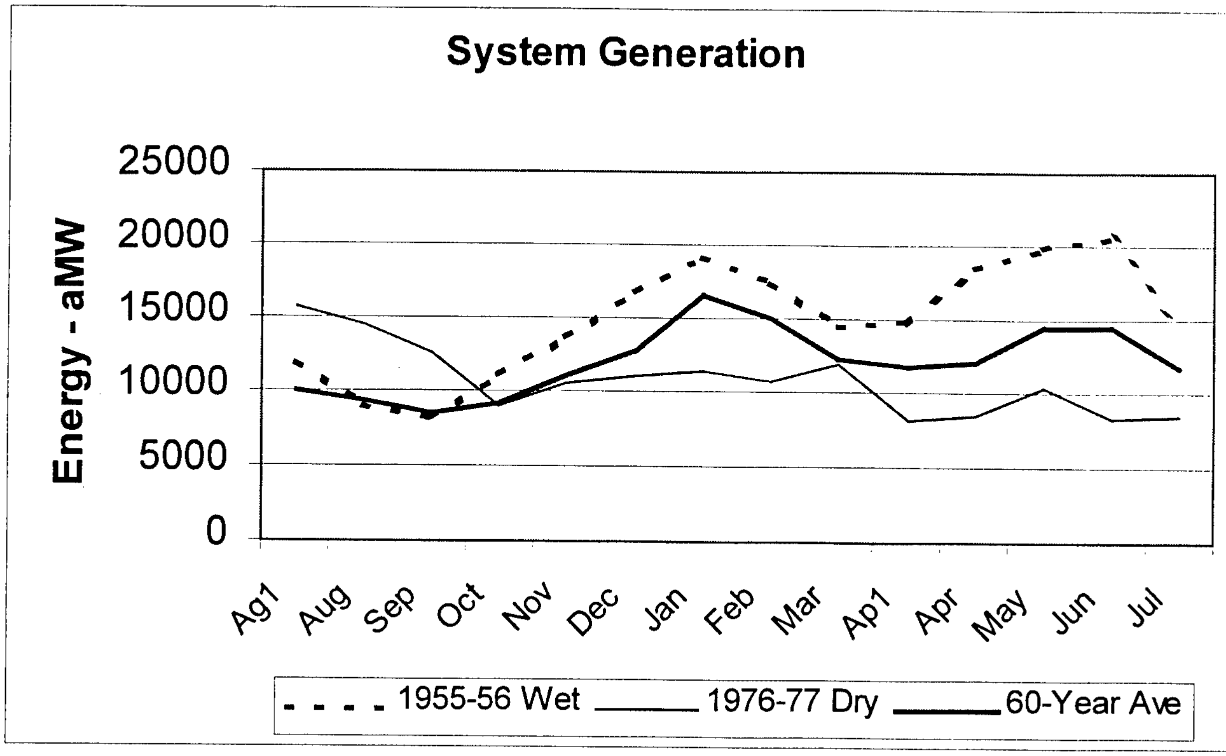


**Figure B-9 Alternative C2 Graphs**



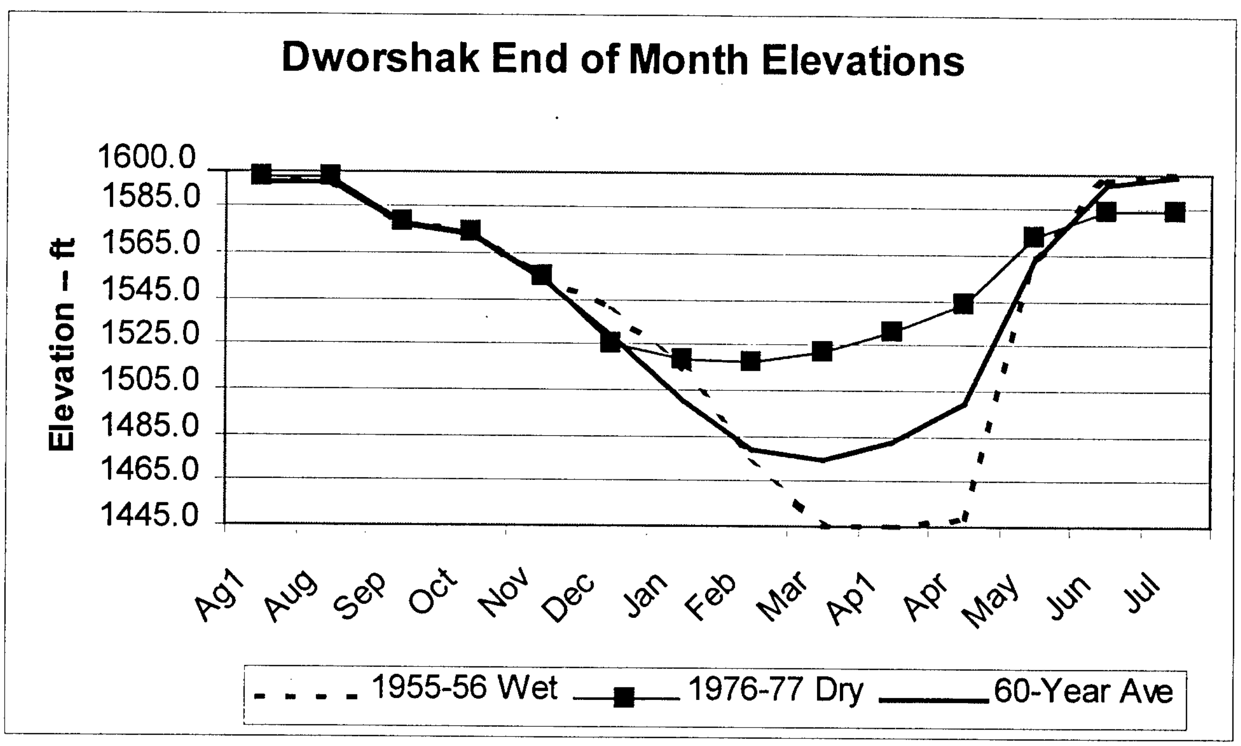
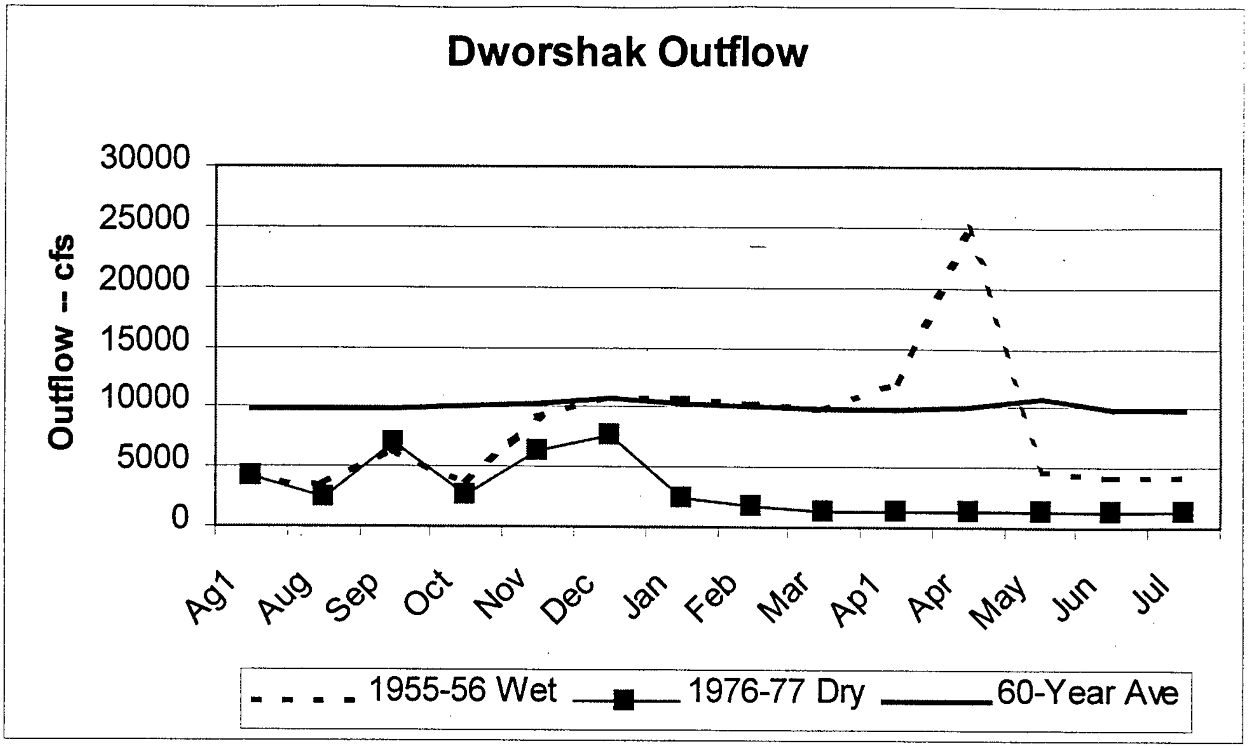



Figure B-9 Alternative C2 Graphs (continued)



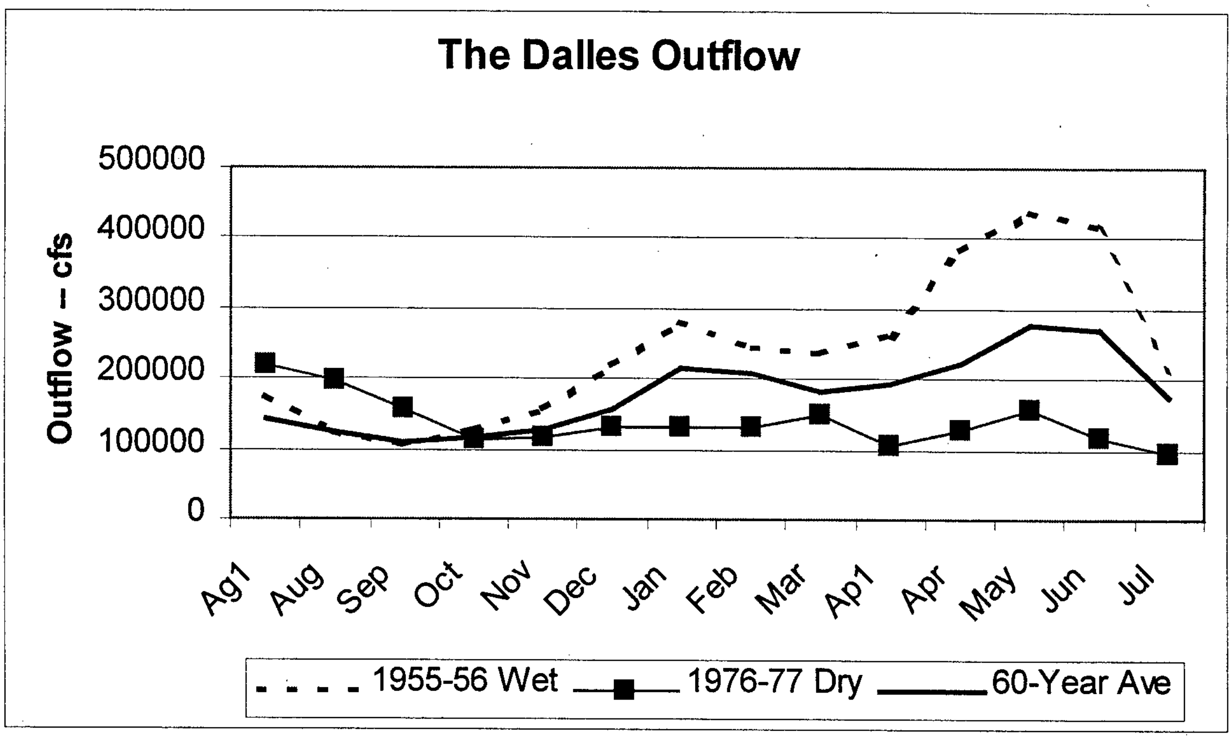
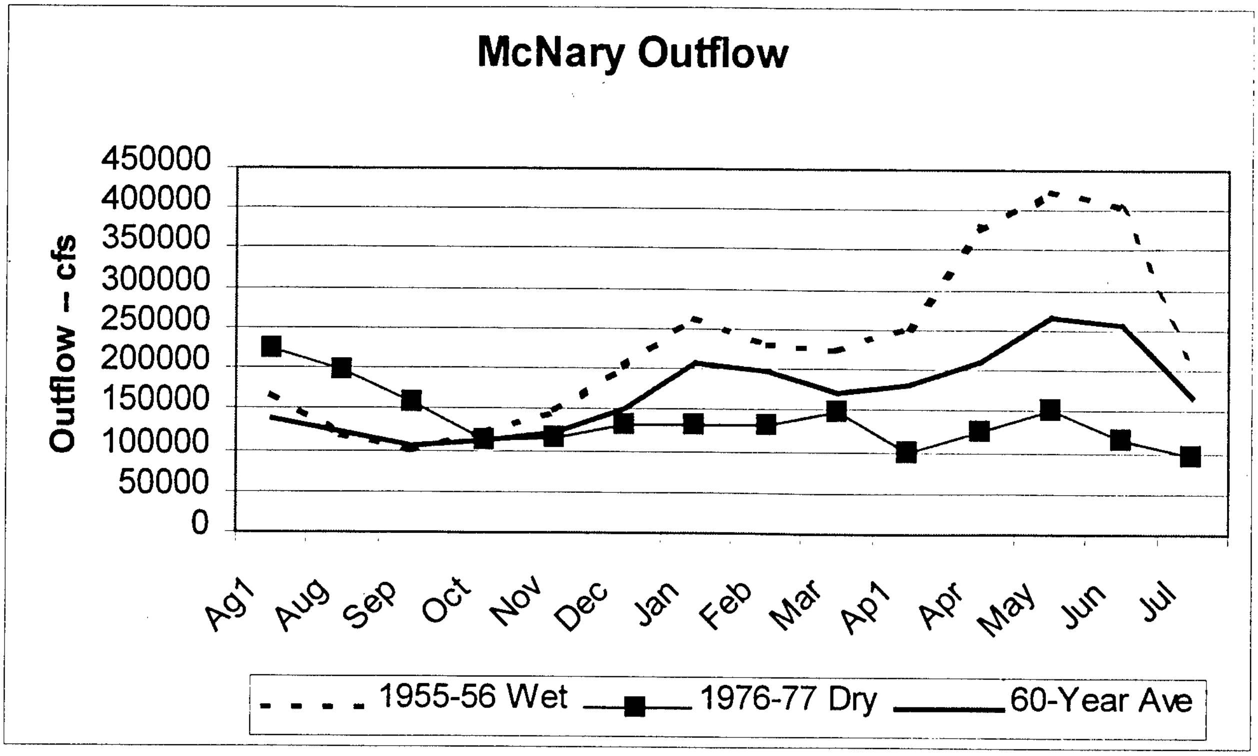



Figure B-9 Alternative C2 Graphs (continued)



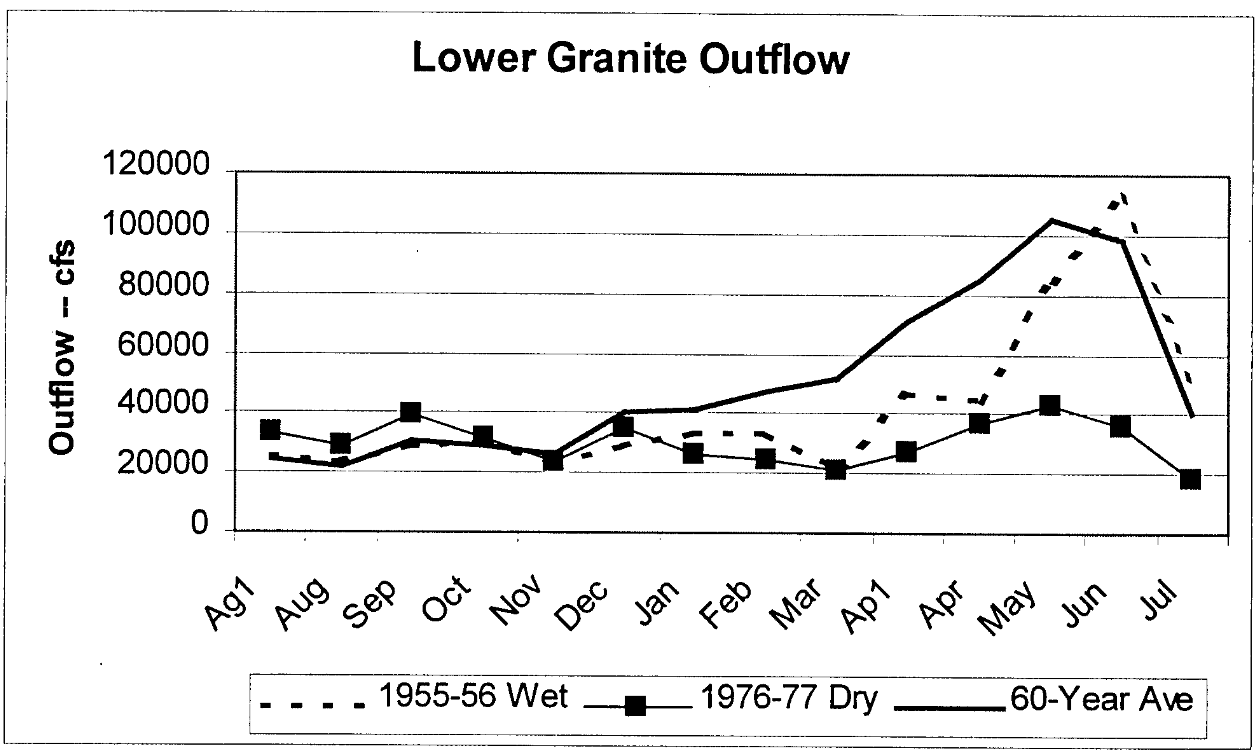
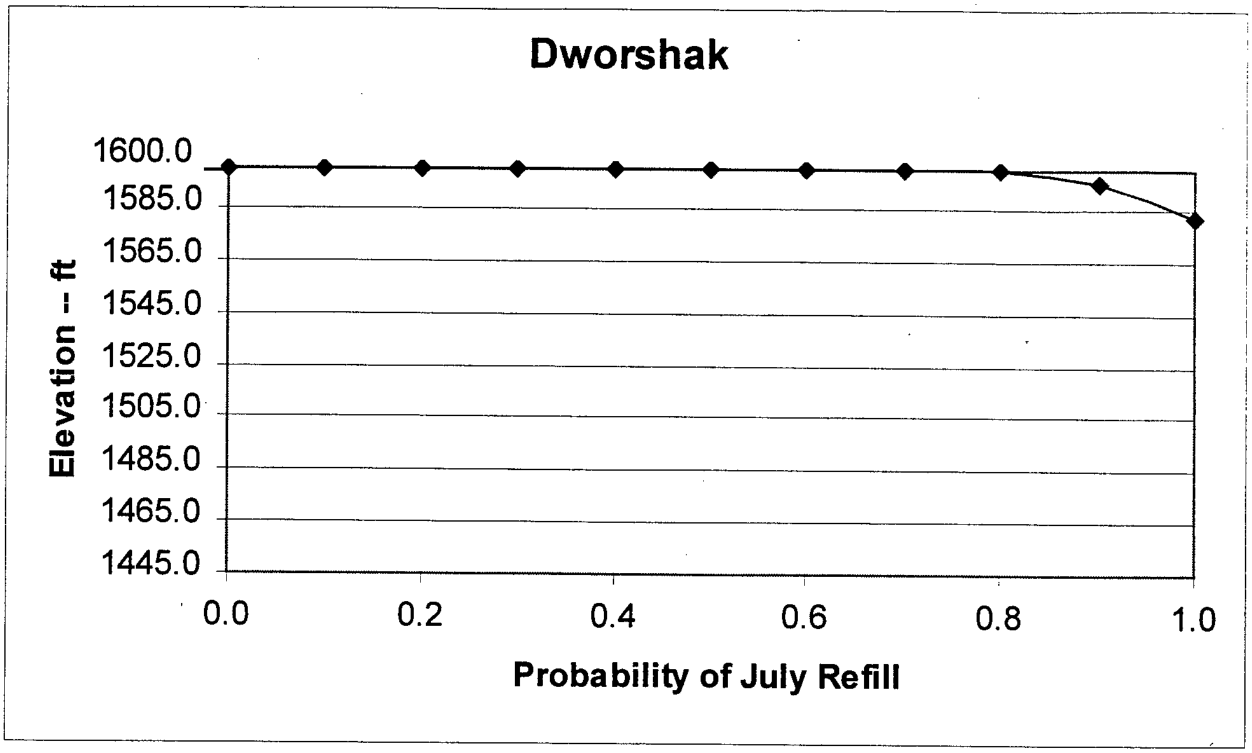



Figure B-9 Alternative C2 Graphs (continued)



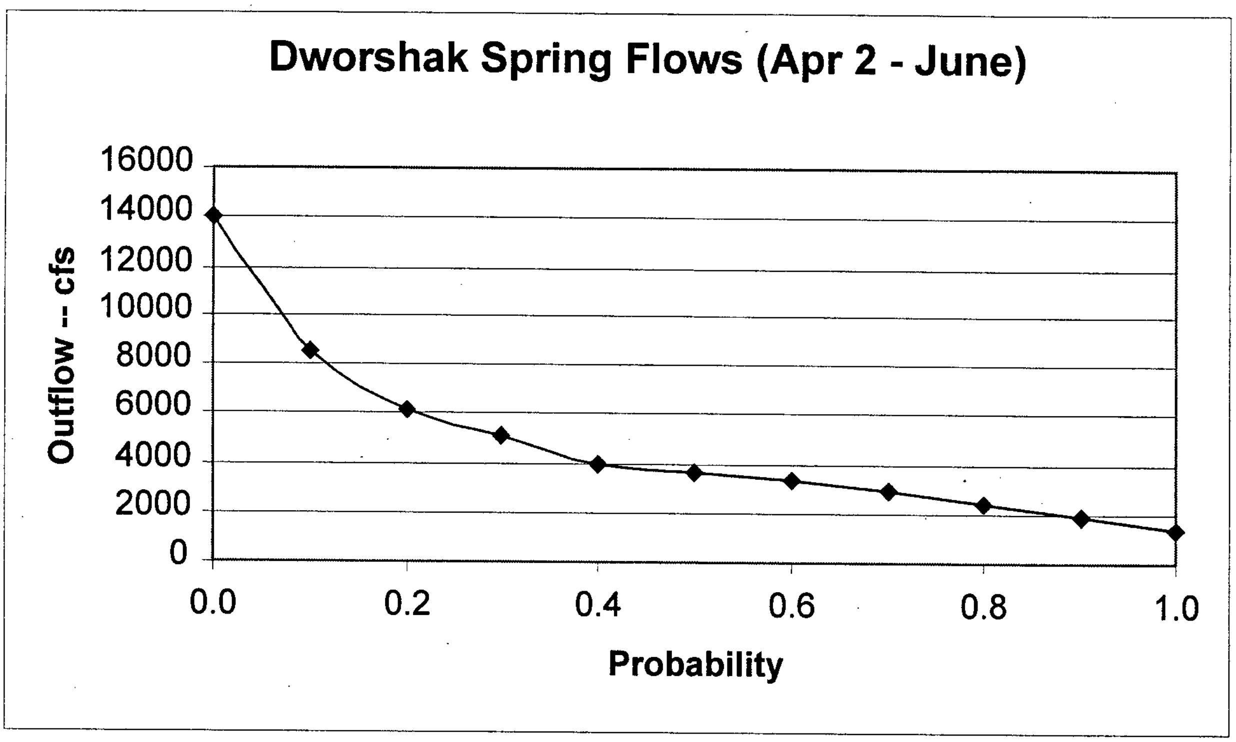
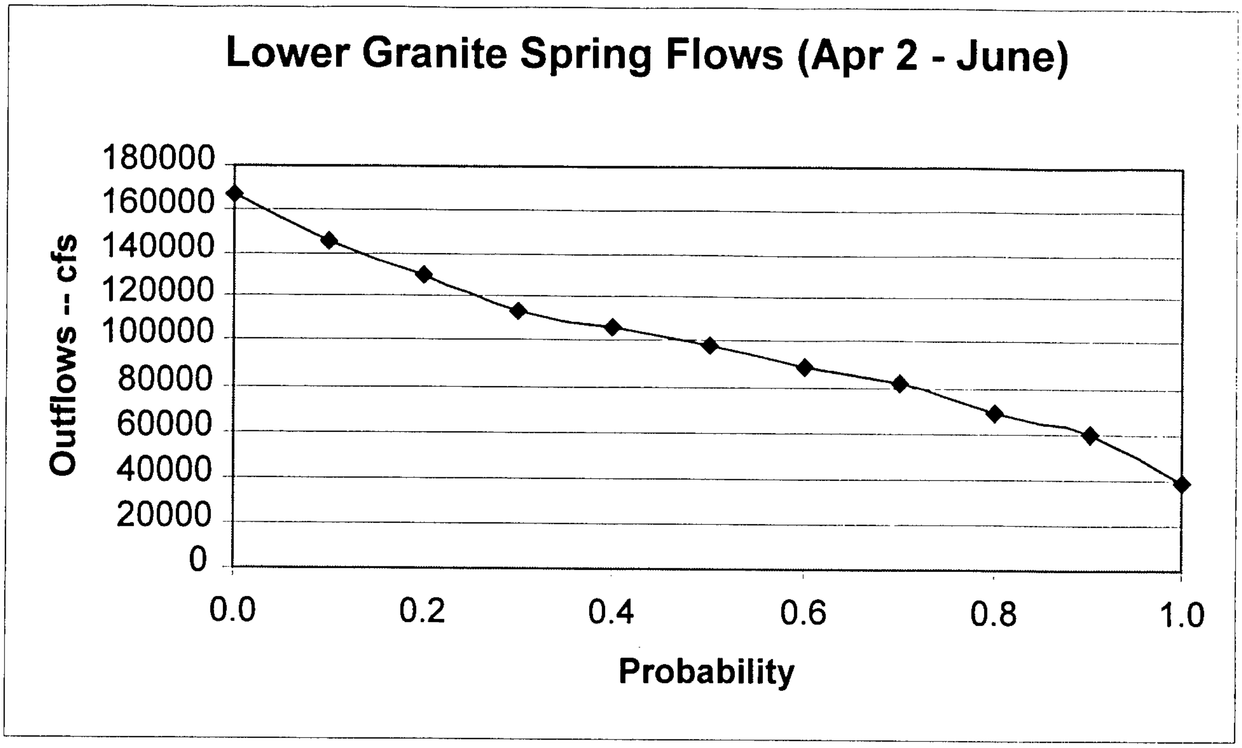



Figure B-9 Alternative C2 Graphs (continued)



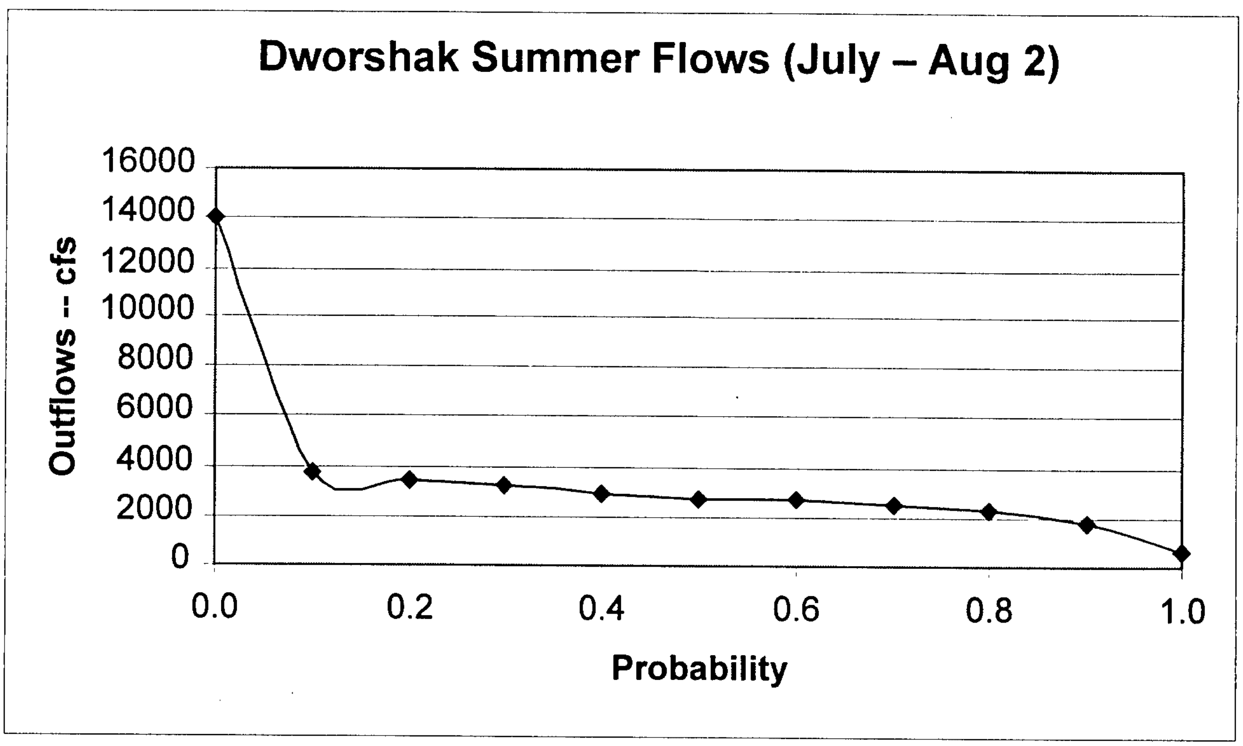
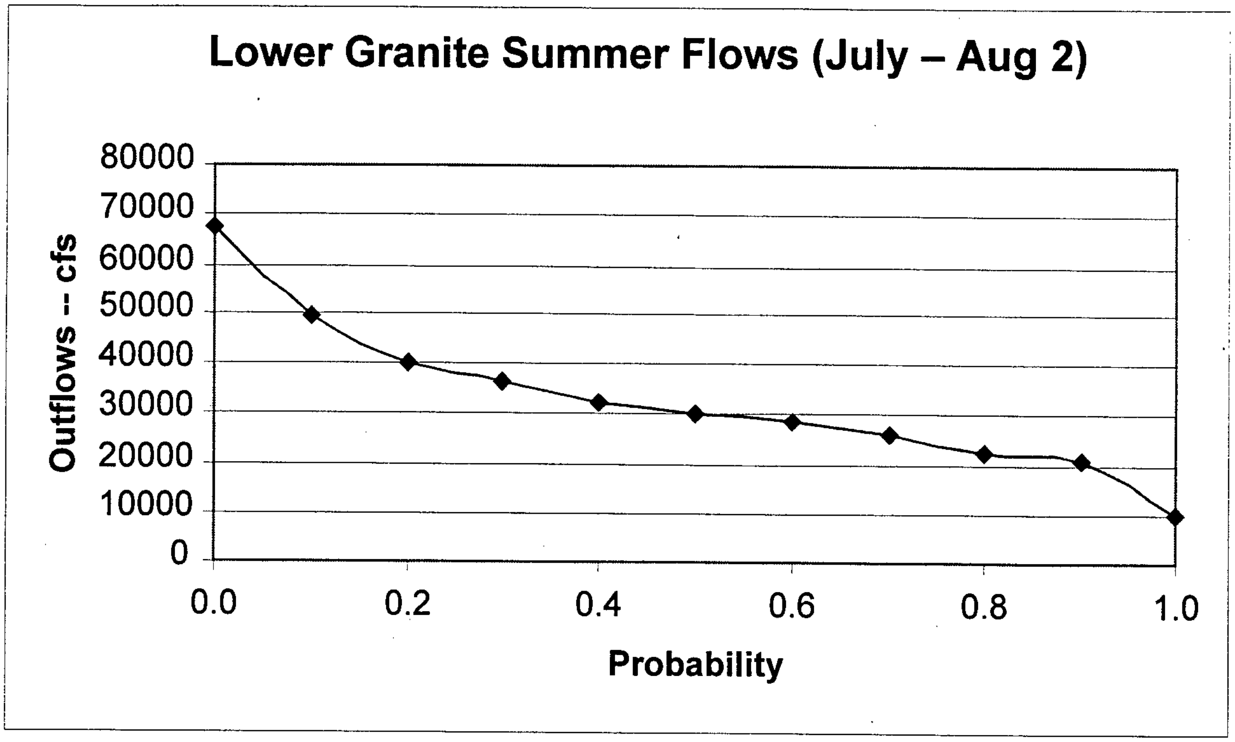



Figure B-9 Alternative C2 Graphs (continued)



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